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FERMENTATION AND ITS BEARINGS ON THE PHENOMENA OF DISEASE.[1]

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IN a book with which we are all familiar, amid other wise utterances, this one occurs: "Cast thy bread upon the waters; for thou shalt find it after many days." In more senses than one this precept is illustrated by my presence here to-night. Firstly, in a general sense, I stand indebted, morally and intellectually, to the poets, historians, and philosophers, of Scotland. Secondly, in a special sense, it so happens that one of the first rootlets of my scientific life derived its nutriment from this city of Glasgow. In early youth it was my ambition to qualify myself for the profession of a civil engineer, and as I grew up one of my aids toward the attainment of this object was the study of a periodical then published in Glasgow, and called *The Practical Mechanic's and Engineer's Magazine.* In that journal I read, with an interest unfelt before, a series of essays on various departments of science—on anatomy and physiology, on geology, on mechanics, on arithmetic, and on natural philosophy and chemistry. Biography and history were also included, while in detached articles various collateral subjects were discussed, such, for example, as the difference between Newton and Leibnitz as to the measure of moving force. It was there that I first learned what Leslie had done in Edinburgh, and what Davy had done in the Royal Institution. And I can now call to mind the day and hour when the yearning to possess such apparatus as Leslie and Davy possessed, and to institute with it such inquiries as they had instituted, rose to a kind of prophetic strength within me—prophetic, for it has come to pass that my own studies as a scientific man have been in great part pursued in that particular domain which had been enriched by the discoveries of Les-

[1] A discourse delivered before the Glasgow Science Lectures Association, October 9, 1876.

lie; while the very instruments used by Davy, and which I first saw figured in the pages of the journal just mentioned, are the identical and familiar instruments with which my lectures in London are now illustrated.

Another point brought more or less home to me in those early days was the injury inflicted on the learner by bad scientific exposition. It does more than the negative damage of withholding instruction. It daunts the young mind, and saps the motive power of self-reliance. This I had experienced; and the essays referred to had this special value for me, that they not only instructed me, but gave me faith in my own capacity to be instructed. Since those days I have written books myself, and in doing so have tried to remember, and to act on the remembrance, that the labor spent in logically ordering one's thoughts, and in saying what one has to say clearly and correctly, is labor well bestowed.

The position assumed at the outset has, I think, been now made good. Glasgow in my case cast its bread upon the waters, and lo! it has returned after many days. Of the nutritive value of the return it is not for me to speak; for it may well have been soured by fortuitous ferments, mixed by the world's tainted atmosphere with the first pure leaven derived from the pages of *The Practical Mechanic's and Engineer's Magazine.*

The figure of speech here employed will become more intelligible as we proceed; for it is my desire and intention to spend the coming hour in speaking to you about *ferments*, not in a metaphorical, but in a real sense. Proper treatment is, I am persuaded, the only thing needed to make the subject both pleasant and profitable to you. For our knowledge of fermentation, and of the ground it covers, has augmented surprisingly of late, while every fresh accession to that knowledge strengthens the hope that its final issues will be of incalculable advantage to mankind.

One of the most remarkable characteristics of the age in which we live is its desire and tendency to connect itself organically with preceding ages—to ascertain how the state of things that now is came to be what it is. And the more earnestly and profoundly this problem is studied, the more clearly comes into view the vast and varied debt which the world of to-day owes to that fore-world in which man, by skill, valor, and well-directed strength, first replenished and subdued the earth. Our prehistoric fathers may have been savages, but they were clever and observant ones. They founded agriculture by the discovery and development of seeds whose origin is now unknown. They tamed and harnessed their animal antagonists, and sent them down to us as ministers, instead of rivals, in the fight for life. Later on, when the claims of luxury added themselves to those of necessity, we find the same spirit of invention at work. We have no historic account of the first brewer, but we glean from history that his art

was practised, and its produce relished, more than two thousand years ago. Theophrastus, who was born nearly four hundred years before Christ, described beer as *the wine of barley*. It is extremely difficult to preserve beer in a hot country; still, Egypt was the land in which it was first brewed, the desire of man to quench his thirst with this exhilarating beverage overcoming all the obstacles which a hot climate threw in the way of its manufacture.

Our remote ancestors had also learned by experience that wine maketh glad the heart of man. Noah, we are informed, planted a vineyard, drank of the wine, and experienced the consequences. But, though wine and beer possess so old a history, a very few years ago no man knew the secret of their formation. Indeed, it might be said that until the present year no thorough and scientific account was ever given of the agencies which come into play in the manufacture of beer, of the conditions necessary to its health, and of the maladies and vicissitudes to which it is subject. Hitherto, indeed, the art and practice of the brewer have resembled those of the physician, both being founded on empirical observation. By this is meant the observation of facts apart from the principles which explain them, and which give the mind an intelligent mastery over them. The brewer learned from long experience the conditions, not the reasons, of success. But he had to contend, and he has still to contend, against unexplained perplexities. Over and over again his care has been rendered nugatory; his beer has fallen into acidity or rottenness, and disastrous losses have been sustained of which he has been unable to assign the cause. It is the hidden enemies against which the physician and the brewer have hitherto contended that recent researches are dragging into the light of day, thus preparing the way for their final extermination.

Let us glance for a moment at the outward and visible signs of fermentation. A few weeks ago I paid a visit to a private still in a Swiss chalet; and this is what I saw: In the peasant's bedroom was a cask with a very large bung-hole carefully closed. The cask contained cherries which had lain in it for fourteen days. It was not entirely filled with the fruit, an air-space being left above the cherries when they were put in. I had the bung removed, and a small lamp dipped into this space. Its flame was instantly extinguished. The oxygen of the air had entirely disappeared, its place being taken by carbonic-acid gas.[1] I tasted the cherries; they were very sour, though when put into the cask they were sweet. The cherries and the liquid associated with them were then placed in a copper boiler, to which a copper head was closely fitted. From the head proceeded a copper tube which passed straight through a vessel of cold water, and issued at the other side. Under the open end of the tube was placed a bottle

[1] The gas which is exhaled from the lungs after the oxygen of the air has done its duty in purifying the blood, the same also which effervesces from soda-water and champagne.

to receive the spirit distilled. The flame of small wood-splinters being applied to the boiler, after a time vapor rose into the head, passed through the tube, was condensed by the cold of the water, and fell in a liquid fillet into the bottle. On being tasted, it proved to be that fiery and intoxicating spirit known in commerce as Kirsch or Kirschwasser.

The cherries, it should be remembered, were here left to themselves, no ferment of any kind being added to them. In this respect what has been said of the cherry applies also to the grape. At the vintage the fruit of the vine is placed in proper vessels, and abandoned to its own action. It ferments, producing carbonic acid; its sweetness disappears, and at the end of a certain time the unintoxicating grape-juice is converted into intoxicating wine. Here, as in the case of the cherries, the fermentation is spontaneous—in what sense spontaneous will appear more clearly by-and-by.

It is needless for me to tell a Glasgow audience that the beer-brewer does not set to work in this way. In the first place the brewer deals not with the juice of fruits, but with the juice of barley. The barley having been steeped for a sufficient time in water, it is drained, and subjected to a temperature sufficient to cause the moist grain to germinate; after which, it is completely dried upon a kiln. It then receives the name of malt. The malt is crisp to the teeth, and decidedly sweeter to the taste than the original barley. It is ground, mashed up in warm water, then boiled with hops until all the soluble portions have been extracted; the infusion thus produced being called the *wort*. This is drawn off, and cooled as rapidly as possible; then, instead of abandoning the infusion, as the wine-maker does, to its own action, the brewer mixes yeast with his wort, and places it in vessels each with only one aperture open to the air. Soon after the addition of the yeast, a brownish froth, which is really new yeast, issues from the aperture, and falls like a cataract into troughs prepared to receive it. This frothing and foaming of the wort is a proof that the fermentation is active.

Whence comes the yeast which issues so copiously from the fermenting-tub? What is this yeast, and how did the brewer become in the first instance possessed of it? Examine its quantity before and after fermentation. The brewer introduces, say, 10 cwts. of yeast; he collects 40, or it may be 50 cwts. The yeast has, therefore, augmented from four to five fold during the fermentation. Shall we conclude that this additional yeast has been spontaneously generated by the wort? Are we not rather reminded of that seed which fell into good ground, and brought forth fruit, some thirty-fold, some sixty-fold, some a hundred-fold? On examination this notion of organic growth turns out to be more than a mere surmise. In the year 1680, when the microscope was still in its infancy, Leeuwenhoek turned the instrument upon this substance, and found it composed of minute globules

suspended in a liquid. Thus knowledge rested until 1835, when Cagniard de la Tour in France, and Schwann in Germany, independently, but animated by a common thought, turned microscopes of improved definition and heightened powers upon yeast, and found it budding and sprouting before their eyes. The augmentation of the yeast alluded to above was thus proved to arise from the growth of a minute plant, now called *Torula* (or *Saccharomyces*) *cerevisiæ*. Spontaneous generation is therefore out of the question. The brewer deliberately sows the yeast-plant, which grows and multiplies in the wort as its proper soil. This discovery marks an epoch in the history of fermentation.

But where did the brewer find his yeast? The reply to this question is similar to that which must be given if the brewer were asked where he found his barley. He has received the seeds of both of them from preceding generations. Could we connect without solution of continuity the present with the past, we should probably be able to trace back the yeast employed by my friend Sir Fowell Buxton today to that employed by some Egyptian brewer two thousand years ago. But you may urge that there must have been a time when the first yeast-cell was generated. Granted—exactly as there was a time when the first barley-corn was generated. Let not the delusion lay hold of you, that a living thing is easily generated, because it is small. Both the yeast-plant and the barley-plant lose themselves in the dim twilight of antiquity, and in this our day there is no more proof of the spontaneous generation of the one than there is of the spontaneous generation of the other.

I stated a moment ago that the fermentation of grape-juice was spontaneous; but I was careful to add, "in what sense spontaneous will appear more clearly by-and-by." Now, this is the sense meant: The wine-maker does not, like the brewer and distiller, deliberately introduce either yeast, or any equivalent of yeast, into his vats; he does not consciously sow in them any plant, or the germ of any plant; indeed, he has been hitherto in ignorance whether plants or germs of any kind have had anything to do with his operations. Still, when the fermented grape-juice is examined, the living *Torula* concerned in alcoholic fermentation never fails to make its appearance. How is this? If no living germ has been introduced into the wine-vat, whence comes the life so invariably developed there?

You may be disposed to reply, with Turpin and others, that, in virtue of its own inherent powers, the grape-juice, when brought into contact with the vivifying atmospheric oxygen, runs spontaneously and of its own accord into these low forms of life. I have not the slightest objection to this explanation, provided proper evidence can be adduced in support of it. But the evidence adduced in its favor, as far as I am acquainted with it, snaps asunder under the least strain of scientific criticism. It is, as far as I can see, the evidence of men

who, however keen and clever as *observers*, are not rigidly-trained *experimenters*. These alone are aware of the precautions necessary in investigations of this delicate kind. In reference, then, to the life of the wine-vat, what is the decision of experiment when carried out by competent men? Let a quantity of the clear, filtered "must" of the grape be boiled, so as to destroy such germs as it may have contracted from the air or otherwise. In contact with germless air the uncontaminated must never ferments. All the materials for spontaneous generation are there, but so long as there is no seed sown there is no life developed, and no sign of that fermentation which is the concomitant of life. Nor need you resort to a boiled liquid. The grape is sealed by its own skin against contamination from without. By an ingenious device, Pasteur has extracted from the interior of the grape its pure juice, and proved that in contact with pure air it never acquires the power to ferment itself, nor to produce fermentation in other liquids.[1] It is not, therefore, in the interior of the grape that the origin of the life observed in the vat is to be sought.

What, then, is its true origin? This is Pasteur's answer, which his well-proved accuracy renders worthy of all confidence: At the time of the vintage little microscopic particles are observed adherent, both to the outer surface of the grape and of the twigs which support the grape. Brush these particles into a capsule of pure water. It is rendered turbid by the dust. Examined by a microscope, these minute particles are seen to present the appearance of organized cells. Instead of receiving them in water, let them be brushed into the pure inert juice of the grape. Forty-eight hours after this is done, our familiar *Torula* is observed budding and sprouting, the growth of the plant being accompanied by all the other signs of active fermentation. What is the inference to be drawn from this experiment? Obviously that the particles adherent to the external surface of the grape are the veritable germs of that life which, after they have been sown in the juice, appears in such profusion. Wine is sometimes objected to on the ground that fermentation is "artificial;" but we notice here the responsibility of Nature. The ferment of the grape is in fact a parasite of the grape, and the art of the wine-maker from time immemorial has consisted in bringing—and it may be added, ignorantly bringing—two things thus closely associated by Nature into actual contact with each other. For thousands of years, what has been done consciously by the brewer has been done unconsciously by the wine-grower. The one has sown his leaven just as much as the other.

Nor is it necessary to impregnate the beer-wort with leaven to provoke fermentation. Abandoned to the contact of our common air,

[1] The liquids of the healthy animal body are also sealed from external contamination. Neither pure urine, collected fresh from the bladder, nor pure blood, drawn with due precautions from the veins, will ever putrefy in contact with pure air.

it sooner or later ferments; but the chances are, that the produce of that fermentation, instead of being agreeable, would be disgusting to the taste. By a rare accident we might get the true alcoholic fermentation, but the odds against obtaining it would be enormous. Pure air acting upon a lifeless liquid will never provoke fermentation; but our ordinary air is the vehicle of numberless germs which act as ferments when they fall into appropriate infusions. Some of them produce acidity, some putrefaction. The germs of our yeast-plant are also in the air; but so sparingly distributed that an infusion like beer-wort, exposed to the air, is almost sure to be taken possession of by foreign organisms. In fact, the maladies of beer are wholly due to the admixture of these objectionable ferments, whose forms and modes of nutrition differ materially from those of the true leaven of beer.

Working in an atmosphere charged with the germs of these organisms, you can understand how easy it is to fall into error in studying the action of any one of them. Indeed, it is only the most accomplished experimenter, who, moreover, avails himself of every means of checking his conclusions, that can walk without tripping through this land of pitfalls. Such a man is the French chemist Pasteur. He has taught us how to separate the commingled ferments of our air, and to study their pure individual action. Guided by him, let us fix our attention more particularly upon the growth and action of the true yeast-plant under different conditions. Let it be sown in a fermentable liquid, which is supplied with plenty of pure air. The plant will flourish in the aërated infusion, and produce large quantities of carbonic-acid gas—a compound, as you know, of carbon and oxygen. The oxygen thus consumed by the plant is the free oxygen of the air, which we suppose to be abundantly supplied to the liquid. The action is so far similar to the respiration of animals, which inspire oxygen and expire carbonic acid. If we examine the liquid even when the vigor of the plant has reached its maximum, we hardly find in it a trace of alcohol. The yeast has grown and flourished, but it has almost ceased to act as a ferment. And could every individual yeast-cell seize, without any impediment, free oxygen from the surrounding liquid, it is certain that it would cease to act as a ferment altogether.

What, then, are the conditions under which the yeast-plant must be placed so that it may display its characteristic quality? Reflection on the facts already referred to suggests a reply, and rigid experiment confirms the suggestion. Consider the Alpine cherries in their closed vessels. Consider the beer in its barrels, with a single small aperture open to the air, through which it is observed not to imbibe oxygen, but to pour forth carbonic acid. Whence come the volumes of oxygen necessary to the production of this latter gas? The small quantity of atmospheric air dissolved in the wort and overlying it would be totally incompetent to supply the necessary oxygen.

In no other way can the yeast-plant obtain the gas necessary for its respiration than by wrenching it from surrounding substances in which the oxygen exists, not free, but in a state of combination. It decomposes the sugar of the solution in which it grows, produces heat, breathes forth carbonic-acid gas, and one of the liquid products of the decomposition is our familiar alcohol. The act of fermentation, then, is a result of the effort of the little plant to maintain its respiration by means of combined oxygen, when its supply of free oxygen is cut off. As defined by Pasteur, fermentation is *life without air.*

But here the knowledge of that thorough investigator comes to our aid to warn us against errors which have been committed over and over again. It is not all yeast-cells that can thus live without air and provoke fermentation. They must be young cells which have caught their vegetative vigor from contact with free oxygen. But, once possessed of this vigor, the yeast may be transplanted into a saccharine infusion absolutely purged of air, where it will continue to live at the expense of the oxygen, carbon, and other constituents of the infusion. Under these new conditions its life, *as a plant*, will be by no means so vigorous as when it had a supply of free oxygen, but its action *as a ferment* will be indefinitely greater.

Does the yeast-plant stand alone in its power of provoking alcoholic fermentation? It would be singular if amid the multitude of low vegetable forms no other could be found capable of acting in a similar way. And here, again, we have occasion to marvel at that sagacity of observation among the ancients to which we owe so vast a debt. Not only did they discover the alcoholic ferment of yeast, but they had to exercise a wise selection in picking it out from others, and giving it special prominence. Place an old boot in a moist place, or expose common paste or a pot of jam to the air: it soon becomes coated with a blue-green mould, which is nothing else than the fructification of a little plant called *Penicillium glaucum.* Do not imagine that the mould has sprung spontaneously from boot, or paste, or jam; its germs, which are abundant in the air, have been sown, and have germinated, in as legal and legitimate a way as thistle-seeds wafted by the wind to a proper soil. Let the minute spores of *Penicillium* be sown in a fermentable liquid, which has been previously boiled in order to kill all other spores or seeds which it may contain; let pure air have free access to the mixture: the *Penicillium* will grow rapidly, striking long filaments into the liquid, and fructifying at its surface. Test the infusion at various stages of the plant's growth: you will never find in it a trace of alcohol. But forcibly submerge the little plant, push it down deep into the liquid, where the quantity of free oxygen that can reach it is insufficient for its needs: it immediately begins to act as a ferment, supplying itself with oxygen by the decomposition of the sugar, and producing alcohol as one of the results of the decomposition. Many other low microscopic plants act in a similar

manner. In aërated liquids they flourish without any production of alcohol, but cut off from free oxygen they act as ferments, producing alcohol exactly as the real alcoholic leaven produces it, only less copiously. For all this knowledge we are indebted to Pasteur.

In the cases hitherto considered, the fermentation is proved to be the invariable correlative of *life*, being produced by organisms foreign to the fermentable substance. But the substance itself may also have within it, to some extent, the motive power of fermentation. The yeast-plant, as we have learned, is an assemblage of living cells; but so at bottom, as shown by Schleiden and Schwann, are all living organisms. Cherries, apples, peaches, pears, plums, and grapes, for example, are composed of cells, each of which is a living unit. And here I have to direct your attention to a point of extreme interest. In 1821, the celebrated French chemist, Bérard, established the important fact that all ripening fruit, exposed to the free atmosphere, absorbed the oxygen of the atmosphere, and liberated an approximately equal volume of carbonic acid. He also found that, when ripe fruits were placed in a confined atmosphere, the oxygen of the atmosphere was first absorbed, and an equal quantity of carbonic acid given out. But the process did not end here. After the oxygen had vanished, carbonic acid, in considerable quantities, continued to be expired by the fruits, which at the same time lost a portion of their sugar, becoming more acid to the taste, though the absolute quantity of acid was not augmented. This was an observation of capital importance, and Bérard had the sagacity to remark that the process might be regarded as a kind of fermentation.

Thus the living cells of fruits can absorb oxygen and breathe out carbonic acid, exactly like the living cells of the leaven of beer. Supposing the access of oxygen suddenly cut off, will the living fruit-cells as suddenly die, or will they continue to live as yeast lives, by extracting oxygen from the saccharine juices round them? This is a question of extreme theoretic significance. It was first answered affirmatively by the able and conclusive experiments of Lechartier and Bellamy, and the answer was subsequently confirmed and explained by the experiments and the reasoning of Pasteur. Bérard only showed the absorption of oxygen and the production of carbonic acid; Lechartier and Bellamy proved the production of alcohol, thus completing the evidence that it was a case of real fermentation. Influenced by his theoretic views, so full was Pasteur of the idea that the cells of a fruit would continue to live at the expense of the sugar of the fruit, that once in his laboratory, while conversing on these subjects with M. Dumas, he exclaimed, "I will wager that if a grape be plunged into an atmosphere of carbonic acid, it will produce alcohol and carbonic acid by the continued life of its own cells—that they will act for a time like the cells of the true alcoholic leaven." He made the experiment, and found the result to

be what he had foreseen. He then extended the inquiry. Placing under a bell-jar twenty-four plums, he filled the jar with carbonic-acid gas; beside it he placed twenty-four similar plums uncovered. At the end of eight days he removed the plums from the jar, and compared them with the others. The difference was extraordinary. The uncovered fruits had become soft, watery, and very sweet; the others were firm and hard, their fleshy portions being not at all watery. They had, moreover, lost a considerable quantity of their sugar. They were afterward bruised, and the juice distilled. It yielded six and a half grammes of alcohol, or one per cent. of the total weight of the plums. Neither in these plums, nor in the grapes first experimented on by Pasteur, could any trace of the ordinary alcoholic leaven be found. The fermentation was the work of the living cells of the fruit itself, after air had been denied to them. When, moreover, the cells were destroyed by bruising, no fermentation ensued. The fermentation was the correlative of a vital act, and it ceased when life was extinguished.

Lüdersdorf was the first to show by this method that yeast acted, not, as Liebig had assumed, in virtue of its *organic*, but in virtue of its *organized*, character. He destroyed the cells of yeast by rubbing them on a ground-glass plate, and found that with the destruction of the organism, though its chemical constituents remained, the power to act as a ferment totally disappeared.

One word more in reference to Liebig may find a place here. To the philosophic chemist thoughtfully pondering these phenomena, familiar with the conception of molecular motion, and the changes produced by the interactions of purely chemical forces, nothing could be more natural than to see in the process of fermentation a simple illustration of molecular instability, the ferment propagating to surrounding molecular groups the overthrow of its own tottering combinations. Broadly considered, indeed, there is a certain amount of truth in this theory; but Liebig, who propounded it, missed the very kernel of the phenomena when he overlooked or contemned the part played in fermentation by microscopic life. He looked at the matter too little with the eye of the body, and too much with the spiritual eye. He practically neglected the microscope, and was unmoved by the knowledge which its revelations would have poured in upon his mind. His hypothesis, as I have said, was natural—nay, it was a striking illustration of Liebig's power to penetrate and unveil molecular actions; but it was an error, and as such has proved an *ignis fatuus* instead of a *pharos* to some of his followers.

I have said that our air is full of the germs of ferments differing from the alcoholic leaven, and sometimes seriously interfering with the latter. They are the weeds of this microscopic garden which often overshadow and choke the flowers. Let us take an illustrative case. Expose boiled milk to the air. It will cool, and then turn

sour, separating like blood into clot and serum. Place a drop of this sour milk under a powerful microscope and watch it closely. You see the minute butter-globules animated by that curious quivering motion called the Brownian motion.[1] But let not this attract your attention too much, for it is another motion that we have now to seek. Here and there you observe a greater disturbance than ordinary among the globules; keep your eye upon the place of tumult, and you will probably see emerging from it a long, eel-like organism, tossing the globules aside and wriggling more or less rapidly across the field of the microscope. Familiar with one sample of this organism, which from its motions receives the name of vibrio, you soon detect numbers of them. It is these organisms which, by decomposing the milk, render it sour. This vibrio is in fact the butyric-acid ferment, as the yeast-plant is the alcoholic ferment. Keep the vibrio and its germs out of your milk and it will never turn sour. But, instead of becoming sour, milk may become putrid. This is due to the action of another living ferment. Examine your putrid milk microscopically, and you find it swarming with organisms much shorter than the vibrios, and manifesting sometimes a wonderful alacrity of motion. Keep this smaller organism and its germs out of your milk and it will never putrefy. Expose a mutton-chop to the air and keep it moist; in summer weather it soon stinks. Place a drop of the juice of the fetid chop under a powerful microscope; it is seen swarming with organisms resembling those in the putrid milk. These organisms, which receive the common name of bacteria,[2] are the agents of all putrefaction. Keep them and their germs from your meat and it will remain forever sweet. Thus we begin to see that within the world of life to which we ourselves belong there is another living world requiring the microscope for its discernment, but which, nevertheless, has the most important bearing on the welfare of the higher life-world.

And now let us reason together as regards the origin of these bacteria. A granular powder is placed in your hands, and you are asked to state what it is. You examine it, and have, or have not, reason to suspect that seeds of some kind are mixed up in it. But you prepare a bed in your garden, sow in it the powder, and soon after find a mixed crop of docks and thistles sprouting from your bed. Until this powder was sown neither docks nor thistles ever made their appearance in your garden. You repeat the experiment once, twice, ten times, fifty times. From fifty different beds after the sowing of the powder you obtain the same crop. What will be your response to the question proposed to you? "I am not in a condition," you would say, "to affirm that every grain of the powder is a dock-seed or a thistle-seed; but I am in a condition to affirm that both dock and

[1] Which I am inclined to regard as an effect of surface tension.

[2] Doubtless organisms exhibiting grave specific differences are grouped together under this common name.

thistle seeds form, at all events, part of the powder." Supposing a succession of such powders to be placed in your hands with grains becoming gradually smaller, until they dwindle to the size of impalpable dust-particles; assuming that you treat them all in the same way, and that from every one of them in a few days you obtain a definite crop—it may be clover, it may be mustard, it may be mignonette, it may be a plant more minute than any of these—the smallness of the particles, or of the plants that spring from them, does not affect the validity of the conclusion. Without a shadow of misgiving you would conclude that the powder must have contained the seeds or germs of the life observed. There is not in the range of physical science an experiment more conclusive nor an inference safer than this one.

Supposing the powder to be light enough to float in the air, and that you are enabled to see it there just as plainly as you saw the heavier powder in the palm of your hand. If the dust sown by the air instead of by the hand produce a definite living crop, with the same logical rigor you would conclude that the germs of this crop must be mixed with the dust. To take an illustration: The spores of the little plant *Penicillium glaucum*, to which I have already referred, are light enough to float in the air. A cut apple, a pear, a tomato, a slice of vegetable marrow, or, as already mentioned, an old moist boôt, a dish of paste, or a pot of jam, constitutes a proper soil for the *Penicillium*. Now, if it could be proved that the dust of the air when sown in this soil produces this plant, while, wanting the dust, neither the air nor the soil, nor both together, can produce it, it would be obviously just as certain in this case that the floating dust contains the germs of *Penicillium* as that the powders sown in your garden contained the germs of the plants which sprung from them.

But how is the floating dust to be rendered visible? In this way: Build a little chamber and provide it with a door, windows, and window-shutters. Let an aperture be made in one of the shutters through which a sunbeam can pass. Close the door and windows, so that no light shall enter save through the hole in the shutter. The track of the sunbeam is at first perfectly plain and vivid in the air of the room. If all disturbance of the air of the chamber be avoided, the luminous track will become fainter and fainter, until at last it disappears absolutely, and no trace of the beam is to be seen. What rendered the beam visible at first? The floating dust of the air, which, thus illuminated and observed, is as palpable to sense as any dust or powder placed on the palm of the hand. In the still air the dust gradually sinks to the floor, or sticks to the walls or ceiling, until, finally, by this self-cleansing process, the air is entirely freed from mechanically suspended matter.

Thus far, I think, we have made our footing sure. Let us proceed. Chop up a beefsteak and allow it to remain for two or three hours

just covered with warm water; you thus extract the juice of the beef in a concentrated form. By properly boiling the liquid and filtering it you can obtain from it a perfectly transparent beef-tea. Expose a number of vessels containing this tea to the moteless air of your chamber, and expose a number of similar vessels containing precisely the same liquid to the dust-laden air. In three days every one of the latter stinks, and, examined with the microscope, every one of them is found swarming with the bacteria of putrefaction. After three months, or three years, the beef-tea within the chamber is found in every case as sweet and clear, and as free from bacteria, as it was at the moment when it was first put in. There is absolutely no difference between the air within and that without, save that the one is dustless and the other dust-laden. Clinch the experiment thus: Open the door of your chamber and allow the dust to enter it. In three days afterward you have every vessel within the chamber swarming with bacteria, and in a state of active putrefaction. Here, also, the inference is quite as certain as in the case of the powder sown in your garden. Multiply your proofs by building fifty chambers instead of one, and by employing every imaginable infusion of wild animals and tame; of flesh, fish, fowl, and viscera; of vegetables of the most various kinds. If, in all these cases, you find the dust infallibly producing its crop of bacteria, while neither the dustless air nor the nutritive infusion, nor both together, are ever able to produce this crop, your conclusion is simply irresistible that the dust of the air contains the germs of the crop which has appeared in your infusions. I repeat, there is no inference of experimental science more certain than this one. In the presence of such facts, to use the words of a paper lately published in the "Philosophical Transactions," it would be simply monstrous to affirm that these swarming crops of bacteria are spontaneously generated.

Is there, then, no experimental proof of spontaneous generation? I answer without hesitation, *none!* But to doubt the experimental proof of a fact, and to deny its possibility, are two different things, though some writers confuse matters by making them synonymous. In fact, this doctrine of spontaneous generation, in one form or another, falls in with the theoretic beliefs of some of the foremost workers of this age; but it is exactly these men who have the penetration to see, and the honesty to expose, the weakness of the evidence adduced in its support.

And here observe how these discoveries tally with the common practices of life. Heat kills the bacteria, cold numbs them. When my housekeeper has pheasants in charge which she wishes to keep sweet, but which threaten to give way, she partially cooks the birds, kills the infant bacteria, and thus postpones the evil day. By boiling her milk she also extends its period of sweetness. Some weeks ago, in the Alps, I made a few experiments on the influence of cold upon

ants. Though the sun was strong, patches of snow still maintained themselves on the mountain-slopes. The ants were found in the warm grass and on the warm rocks adjacent. Transferred to the snow, the rapidity of their paralysis was surprising. In a few seconds a vigorous ant, after a few languid struggles, would wholly lose its power of locomotion, and lie practically dead upon the snow. Transferred to the warm rock it would revive, to be again smitten with death-like numbness when retransferred to the snow. What is true of the ant is specially true of our bacteria. Their active life is suspended by cold, and with it their power of producing or continuing putrefaction. This is the whole philosophy of the preservation of meat by cold. The fish-monger, for example, when he surrounds his very assailable wares by lumps of ice, stays the process of putrefaction by reducing to numbness and inaction the organisms which produce it, and in the absence of which his fish would continue sweet and sound. It is the astonishing activity into which these bacteria are pushed by warmth that renders a single summer's day sometimes so disastrous to the great butchers of London and Glasgow. The bodies of guides lost in the crevices of Alpine glaciers have come to the surface forty years after their interment without the flesh showing any sign of putrefaction. But the most astonishing case of this kind is that of the hairy elephant of Siberia which was found incased in ice. It had been buried for ages, but when laid bare its flesh was sweet, and for some time afforded copious nutriment to the wild beasts which fed upon it.

Beer is assailable by all the organisms here referred to, some of which produce acetic, some lactic, and some butyric acid, while yeast is open to attack from the bacteria of putrefaction. In relation to the particular beverage the brewer wishes to produce, these foreign ferments have been properly called *ferments of disease.* The cells of the true leaven are globules, usually somewhat elongated. The other organisms are more or less rod-like or eel-like in shape, some of them being beaded so as to resemble necklaces. Each of these organisms produces a fermentation and a flavor peculiar to itself. Keep them out of your beer and it remains forever unaltered. Never without them will your beer contract disease. But their germs are in the air, in the vessels employed in the brewery, even in the yeast used to impregnate the wort. Consciously or unconsciously, the whole art of the brewer is directed against them. His aim is to paralyze if he cannot annihilate them.

For beer, moreover, the question of temperature is one of supreme importance; indeed, the recognized influence of temperature is causing on the Continent of Europe a complete revolution in the manufacture of beer. When I was a student in Berlin, in 1851, there were certain places specially devoted to the sale of Bavarian beer, which was then making its way into public favor. The beer is prepared by what is called the process of *low fermentation;* the name being

given partly because the yeast of this beer, instead of rising to the top and issuing through the bung-hole, falls to the bottom of the cask; but partly, also, because it is produced at a low temperature. The other and older process, called *high fermentation*, is far more handy, expeditious, and cheap. In high fermentation eight days suffice for the production of the beer; in low fermentation, ten, fifteen, even twenty days, are found necessary. Vast quantities of ice, moreover, are consumed in the process of low fermentation. In the single brewery of Dreher, of Vienna, 100,000,000 pounds of ice are consumed annually in cooling the wort and beer. Notwithstanding these obvious and weighty drawbacks, the low fermentation is rapidly displacing the high upon the Continent. Here are some statistics which show the number of breweries of both kinds existing in Bohemia in 1860, 1865, and 1870:

	1860.	1865.	1870.
High fermentation . .	281	81	18
Low fermentation . .	135	459	831

Thus in ten years the number of high-fermentation breweries fell from 281 to 18, while the number of low-fermentation breweries rose from 135 to 831. The sole reason for this vast change—a change which involves a greater expenditure of time, labor, and money—is the additional command which it gives the brewer over the fortuitous ferments of disease. These ferments, which, it is to be remembered, are living organisms, have their activity suspended by temperatures below 10° C., and as long as they are reduced to torpor the beer remains untainted either by acidity or putrefaction. The beer of low fermentation is brewed in winter, and kept in cool cellars; the brewer being thus enabled to dispose of it at his leisure, instead of forcing its consumption to avoid the loss involved in its alteration if kept too long. Hops, it may be remarked, act to some extent as an antiseptic to beer. The essential oil of the hop is bactericidal: hence the strong impregnation with hop-juice of all beer intended for exportation.

These low organisms, which one might be disposed to regard as the beginnings of life, were we not warned that the microscope, precious and perfect as it is, has no power to show us the real beginnings of life, are by no means purely useless or purely mischievous in the economy of Nature. They are only noxious when out of their proper place. They exercise a useful and valuable function as the burners and consumers of dead matter, animal and vegetable, reducing such matter, with a rapidity otherwise unattainable, to innocent carbonic acid and water. Furthermore, they are not all alike, and it is only restricted classes of them that are really dangerous to man. One difference in their habits is worthy of special reference here. Air, or rather the oxygen of the air, which is absolutely necessary to the support of the bacteria of putrefaction, is absolutely deadly to

the vibrios which provoke the butyric-acid fermentation. This is most simply illustrated by the following beautiful observation of Pasteur: You know the way of looking at these small organisms through the microscope. A drop of the liquid containing them is placed upon glass, and on the drop is placed a circle of exceedingly thin glass; for, to magnify them sufficiently, it is necessary that the microscope should come very close to the organisms. Round the edge of the circular plate of glass the liquid is in contact with the air, and incessantly absorbs it, including the oxygen. Here, if the drop be charged with bacteria, we have a zone of very lively ones. But through this living zone, greedy of oxygen and appropriating it, the vivifying gas cannot penetrate to the centre of the film. In the middle, therefore, the bacteria die, while their peripheral colleagues continue active. If a bubble of air chance to be inclosed in the film, round it the bacteria will pirouette and wabble until its oxygen has been absorbed, after which all their motions cease. Precisely the reverse of all this occurs with the vibrios of butyric acid. In their case it is the peripheral organisms that are first killed, the central ones remaining vigorous while ringed by a zone of dead. Pasteur, moreover, filled two vessels with a liquid containing these vibrios: through one vessel he led air, and killed its vibrios in half an hour; through the other he led carbonic acid, and after three hours found the vibrios fully active. It was while observing these differences of deportment fifteen years ago that the thought of life without air, and its bearing upon the theory of fermentation, flashed upon the mind of this admirable investigator.

And here I am tempted to inquire how it is that during the last five or six years so many of the cultivated English and American public, including members of the medical profession and contributors to some of our most intellectual journals, could be so turned aside as they have been from the pure well-spring of scientific truth to be found in the writings of Pasteur? The reason I take to be, that, while against unsound logic a healthy mind can always defend itself, against unsound experiment without discipline it is defenseless. To judge of the soundness of scientific data, and to reason from data assumed to be sound, are two totally different things. The one deals with the raw material of fact, the other with the logical textures woven from that material. Now, the logical loom may go accurately through all its motions, while the woven fibres may be all rotten. It is this inability, through lack of education in experiment, to judge of the soundness of experimental work, which lies at the root of the defection from Pasteur.

I will cite an example of this mistake of judgment. Between the large-type articles and the reviews of the *Saturday Review* essays on various subjects are interpolated. On Alpine slopes and in the calm of summer evenings, while reading these brief essays, I have been

many a time impressed, not only with their sparkling cleverness, but with their deep-searching wisdom and their wealth of spiritual experience. In this central region of the *Review* the question of spontaneous generation has been taken up and discussed. The writer is not a whit behind his colleagues in literary brilliancy and logical force. But, having no touchstone in his own experience to enable him to distinguish a good experiment from a bad one, he has committed, on the point of the gravest practical import, the influence of the powerful journal in which he writes to the support of error. It is only, I would repeat, by practice among facts that the intellect is prepared to judge of facts, and no mere logical acuteness or literary skill can atone for the want of this necessary education.

We now approach an aspect of this question which concerns us still more closely, and which will be best illustrated by an actual fact. A few years ago I was bathing in an Alpine stream, and, returning to my clothes from the cascade which had been my shower-bath, I slipped upon a block of granite, the sharp crystals of which stamped themselves into my naked shin. The wound was an awkward one, but, being in vigorous health at the time, I hoped for a speedy recovery. Dipping a clean pocket-handkerchief into the stream, I wrapped it round the wound, limped home, and remained for four or five days quietly in bed. There was no pain, and at the end of this time I thought myself quite fit to quit my room. The wound, when uncovered, was found perfectly clean, uninflamed, and entirely free from pus. Placing over it a bit of gold-beater's-skin, I walked about all day. Toward evening itching and heat were felt; a large accumulation of pus followed, and I was forced to go to bed again. The water-bandage was restored, but it was powerless to check the action now set up; arnica was applied, but it made matters worse. The inflammation increased alarmingly, until finally I was ignobly carried on men's shoulders down the mountain, and transported to Geneva, where, thanks to the kindness of friends, I was immediately placed in the best medical hands. On the morning after my arrival in Geneva, Dr. Gautier discovered an abscess in my instep, at a distance of five inches from the wound. The two were connected by a channel, or *sinus*, as it is technically called, through which he was able to empty the abscess without the application of the lance.

By what agency was that channel formed—what was it that thus tore asunder the sound tissue of my instep, and kept me for six weeks a prisoner in bed? In the very room where the water-dressing had been removed from my wound and the gold-beater's-skin applied to it, I opened this year a number of tubes, containing perfectly clear and sweet infusions of fish, flesh, and vegetable. These hermetically-sealed infusions had been exposed for weeks, both to the sun of the Alps and to the warmth of a kitchen, without showing the slightest turbidity or sign of life. But two days after they were opened the

greater number of them swarmed with the bacteria of putrefaction, the germs of which had been contracted from the dust-laden air of the room. And, had the pus from my abscess been examined, my memory of its appearance leads me to infer that it would have been found equally swarming with these bacteria—that it was their germs which got into my incautiously-opened wound. They were the subtile workers that burrowed down my shin, dug the abscess in my instep, and produced effects which might well have proved fatal to me.

And here we come directly face to face with the labors of a man who has established for himself an imperishable reputation in relation to this subject, who combines the penetration of the true theorist with the skill and conscientiousness of the true experimenter, and whose practice is one continued demonstration of the theory that the putrefaction of wounds is to be averted by the destruction of the germs of bacteria. Not only from his own reports of his cases, but from the reports of eminent men who have visited his hospital, and from the opinions expressed to me by Continental surgeons, do I gather that one of the greatest steps ever made in the art of surgery was the introduction of the antiseptic system of treatment, practised first in Glasgow and now in Edinburgh, by Prof. Lister.

The interest of this subject does not slacken as we proceed. We began with the cherry-cask and beer-vat; we end with the body of man. There are persons born with the power of interpreting natural facts, as there are others smitten with everlasting incompetence in regard to such interpretation. To the former class in an eminent degree belonged the celebrated philosopher Robert Boyle, whose words in relation to this subject have in them the forecast of prophecy. "And let me add," writes Boyle in his "Essay on the Pathological Part of Physik," "that he that thoroughly understands the nature of ferments and fermentations shall probably be much better able than he that ignores them to give a fair account of divers phenomena of several diseases (as well fevers as others) which will perhaps be never properly understood without an insight into the doctrine of fermentations."

Two hundred years have passed since these pregnant words were written, and it is only in this our day that men are beginning to fully realize their truth. In the domain of surgery the justice of Boyle's surmise has been most strictly demonstrated. Demonstration is indeed the only word which fitly characterizes the evidence brought forward by Prof. Lister. You will grasp in a moment his leading idea. Take the extracted juice of beef or mutton, so prepared as to be perfectly transparent, and entirely free from the living germs of bacteria. Into the clear liquid let fall the tiniest drop of an infusion charged with the bacteria of putrefaction. Twenty-four hours subsequently the clear extract will be found muddy throughout, the turbidity being due to swarms of bacteria generated by the drop with

which the infusion was inoculated. At the same time the infusion will have passed from a state of sweetness to a state of putridity. Let a drop similar to that which has produced this effect fall into an open wound: the juices of the living body nourish the bacteria as the beef or mutton juice nourished them, and you have putrefaction produced within the system. The air, as I have said, is laden with floating matter which, when it falls upon the wound, acts substantially like the drop. Prof. Lister's aim is to destroy the life of that floating matter—to kill such germs as it may contain. Had he, for example, dressed my wound, instead of opening it incautiously in the midst of air laden with the germs of bacteria, and instead of applying to it gold-beater's-skin, which probably carried these germs upon its surface, he would have showered upon the wound, during the time of dressing, the spray of some liquid capable of killing the germs. The liquid usually employed for this purpose is dilute carbolic acid, which, in his skilled hands, has become a specific against putrefaction and all its deadly consequences.

We now pass the bounds of surgery proper, and enter the domain of epidemic disease, including those fevers so sagaciously referred to by Boyle. The most striking analogy between a *contagium* and a ferment is to be found in the power of indefinite self-multiplication possessed and exercised by both. You know the exquisitely truthful figures regarding leaven employed in the New Testament. A particle hid in three measures of meal leavens it all. A little leaven leaveneth the whole lump. In a similar manner a particle of *contagium* spreads through the human body and may be so multiplied as to strike down whole populations. Consider the effect produced upon the system by a microscopic quantity of the virus of small-pox. That virus is to all intents and purposes a seed. It is sown as leaven is sown, it grows and multiplies as leaven grows and multiplies, and it always reproduces itself. To Pasteur we are indebted for a series of masterly researches, wherein he exposes the looseness and general baselessness of prevalent notions regarding the transmutation of one ferment into another. He guards himself against saying it is impossible. The true investigator is sparing in the use of this word, though the use of it is unsparingly ascribed to him; but, as a matter of fact, Pasteur has never been able to effect the alleged transmutation, while he has been always able to point out the open doorways through which the affirmers of such transmutations had allowed error to march in upon them.[1]

The great source of error here has been already alluded to in this discourse. The observers worked in an atmosphere charged with the germs of different organisms; the mere accident of first possession

[1] Those who wish for an illustration of the care necessary in these researches, and of the carelessness with which they have in some cases been conducted, will do well to consult the Rev. W. H. Dallinger's excellent "Notes on Heterogenesis," in the October number of the *Popular Science Review*.

rendering now one organism, now another, triumphant. In different stages, moreover, of its fermentative or putrefactive changes, the same infusion may so alter as to be successively taken possession of by different organisms. Such cases have been adduced to show that the earlier organisms must have been transformed into the later ones, whereas they are simply cases in which different germs, because of changes in the infusion, render themselves valid at different times.

By teaching us how to cultivate each ferment in its purity—in other words, by teaching us how to rear the individual organism apart from all others—Pasteur has enabled us to avoid all these errors. And where this isolation of a particular organism has been duly effected it grows and multiplies indefinitely, but no change of it into another organism is ever observed. In Pasteur's researches the Bacterium remained a Bacterium, the Vibrio a Vibrio, the Penicillium a Penicillium, and the Torula a Torula. Sow any of these in a state of purity in an appropriate liquid, you get it, and it alone, in the subsequent crop. In like manner, sow small-pox in the human body, your crop is small-pox. Sow there scarlatina, and your crop is scarlatina. Sow typhoid virus, your crop is typhoid—cholera, your crop is cholera. The disease bears as constant a relation to its contagium as the microscopic organisms just enumerated do to their germs, or indeed as a thistle does to its seed. No wonder, then, with analogies so obvious and so striking, that the conviction is spreading and growing daily in strength that reproductive parasitic life is at the root of epidemic disease—that living ferments finding lodgment in the body increase there and multiply, directly ruining the tissue on which they subsist, or destroying life indirectly by the generation of poisonous compounds within the body. This conclusion, which comes to us with a presumption almost amounting to demonstration, is clinched by the fact that virulently-infective diseases have been discovered with which living organisms are as closely and as indissolubly associated as the growth of Torula is with the fermentation of beer.

And here, if you will permit me, I would utter a word of warning to well-meaning people. We have now reached a phase of this question when it is of the very last importance that light should once for all be thrown upon the manner in which contagious and infectious diseases take root and spread. To this end the action of various ferments upon the organs and tissues of the living body must be studied; the habitat of each special organism concerned in the production of each specific disease must be determined, and the mode by which its germs are spread abroad as sources of further infection. It is only by such rigidly accurate inquiries that we can obtain final and complete mastery over these destroyers. Hence, while abhorring cruelty of all kinds, while shrinking sympathetically from all animal suffering—suffering which my own pursuits never call upon me to inflict—an unbiased survey of the field of research now open-

ing out before the physiologist causes me to conclude that no greater calamity could befall the human race than the stoppage of experimental inquiry in this direction. A lady whose philanthropy has rendered her illustrious said to me, some time ago, that science was becoming immoral; that the researches of the past, unlike those of the present, were carried on without cruelty. I replied to her that the science of Kepler and Newton, to which she referred, dealt with the laws and phenomena of inorganic Nature; but that one great advance made by modern science was in the direction of biology, or the science of life; and that in this new direction scientific inquiry, though at the outset pursued at the cost of some temporary suffering, would in the end prove a thousand times more beneficent than it had ever hitherto been. I said this because I saw that the very researches which the lady deprecated were leading us to such a knowledge of epidemic diseases as will enable us finally to sweep these scourges of the human race from the face of this fair earth.

This is a point of such special importance that I should like to bring it home to your intelligence by a single trustworthy illustration. In 1850, two distinguished French observers, MM. Davainne and Rayer, noticed, in the blood of animals which had died of the virulent disease called *splenic fever*, small microscopic organisms resembling transparent rods, but neither of them at that time attached any significance to the observation. In 1861 Pasteur published a memoir on the fermentation of butyric acid, wherein he described the organism which provoked it; and, after reading this memoir, it occurred to Davainne that splenic fever might be a case of fermentation set up within the animal body by the organisms which had been observed by him and Rayer. This idea has been placed beyond all doubt by subsequent research.

Some years in advance of the labors undertaken by Davainne, observations of the highest importance had been made on splenic fever by Pollender and Brauell. Two years ago, Dr. Burdon-Sanderson gave us a very clear account of what was known up to that time of this disorder. With regard to the permanence of the contagium, it had been proved to hang for years about localities where it had once prevailed; and this seemed to show that the rod-like organisms could not constitute the contagium, because their infective power was found to vanish in a few weeks. But other facts established an intimate connection between the organisms and the disease, so that a review of all the facts caused Dr. Sanderson to conclude that the contagium existed in two distinct forms: the one "fugitive," and visible as transparent rods; the other permanent but "latent," and not yet brought within the grasp of the microscope.

At the time that Dr. Sanderson was writing this report, a young German physician, named Koch, occupied with the duties of his profession in an obscure country district, was already at work, applying,

during his spare time, various original and ingenious devices to the investigation of splenic fever. He studied the habits of the rod-like organisms, and found the aqueous humor of an ox's eye to be particularly suitable for their nutrition. With a drop of the aqueous humor he mixed the tiniest speck of a liquid containing the rods, placed the drop under his microscope, warmed it suitably, and observed the subsequent action. During the first two hours hardly any change was noticeable; but at the end of this time the rods began to lengthen, and the action was so rapid that at the end of three or four hours they attained from ten to twenty times their original length. At the end of a few additional hours they had formed filaments in many cases a hundred times the length of the original rods. The same filament, in fact, was frequently observed to stretch through several fields of the microscope. Sometimes they lay in straight lines parallel to each other; in other cases they were bent, twisted, and coiled, into the most graceful figures; while sometimes they formed knots of such bewildering complexity that it was impossible for the eye to trace the individual filaments through the confusion.

Had the observation ended here an interesting scientific fact would have been added to our previous store, but the addition would have been of little practical value. Koch, however, continued to watch the filaments, and after a time noticed little dots appearing within them. These dots became more and more distinct, until finally the whole length of the organism was studded with minute ovoid bodies, which lay within the outer integument like peas within their shell. By-and-by the integument fell to pieces, the place of the organism being taken by a long row of seeds or spores. These observations, which were confirmed in all respects by the celebrated naturalist Cohn, of Breslau, are of the first importance. They clear up the existing perplexity regarding the latent and visible contagia of splenic fever; for, in the most conclusive manner, Koch proved the spores, as distinguished from the rods, to constitute the contagium of the fever in its most deadly and persistent form.

How did he reach this important result? Mark the answer. There was but one way open to him to test the activity of the contagium, and that was the inoculation with it of living animals. He operated upon Guinea-pigs and rabbits, but the vast majority of his experiments were made with mice. Inoculating them with the fresh blood of an animal suffering from splenic fever, they invariably died of the same disease within twenty or thirty hours after inoculation. He then sought to determine how the contagium maintained its vitality. Drying the infectious blood containing the rod-like organisms, in which, however, the spores were not developed, he found the contagium to be that which Dr. Sanderson calls "fugitive." It maintained its power of infection for five weeks at the farthest. He then dried blood containing the fully-developed spores, and exposed the sub-

stance to a variety of conditions. He permitted the dried blood to assume the form of dust; wetted this dust, allowed it to dry again, permitted it to remain for an indefinite time in the midst of putrefying matter, and subjected it to various other tests. After keeping the spore-charged blood which had been treated in this fashion for four years, he inoculated a number of mice with it, and found its action as fatal as that of blood fresh from the veins of an animal suffering from splenic fever. There was no single escape from death after inoculation by this deadly contagium. Uncounted millions of these spores are developed in the body of every animal which has died of splenic fever, and every spore of these millions is competent to produce the disease. The name of this formidable parasite is *Bacillus anthracis*.[1]

Now, the very first step toward the extirpation of these contagia is the knowledge of their nature; and the knowledge brought to us by Dr. Koch will render as certain the stamping out of splenic fever as the stoppage of the plague of *pébrine* by the researches of Pasteur. One small item of statistics will show what this implies. In the single district of Novgorod in Russia, between the years 1867 and 1870, over 56,000 cases of death by splenic fever, among horses, cows, and sheep, were recorded. But its ravages did not confine themselves to the animal world, for, during the time and in the district referred to, 528 human beings perished in the agonies of the same disease.

A description of the fever will help you to come to a right decision on the point which I wish to submit to your consideration. "An animal," says Dr. Burdon-Sanderson, "which perhaps for the previous day has declined food and shown signs of general disturbance, begins to shudder and to have twitches of the muscles of the back, and soon after becomes weak and listless. In the mean time the respiration becomes frequent and often difficult, and the temperature rises to three or four degrees above the normal; but soon convulsions, affecting chiefly the muscles of the back and loins, usher in the final collapse, of which the progress is marked by complete loss of power of moving the trunk or extremities, diminution of temperature, mucous and sanguinolent alvine evacuations, and similar discharges from the mouth and nose." In a single district of Russia, as above remarked, 56,000 horses, cows, and sheep, and 528 men and women, perished in this way during a period of two or three years. What the annual fatality is throughout Europe I have no means of knowing. Doubtless it must be very great. The question, then, which I wish to submit to your judgment is this: Is the knowledge which reveals

[1] To produce its characteristic effects the contagium of splenic fever must enter the blood. The virulently-infective spleen of a diseased animal may be eaten with impunity by mice. On the other hand, the disease refuses to be communicated by inoculation to dogs, partridges, or sparrows. In their blood *Bacillus anthracis* ceases to act as a ferment.

to us the nature, and which assures the extirpation, of a disorder so virulent and so vile, worth the price paid for it? It is exceedingly important that assemblies like the present should see clearly the issues at stake in such questions as this, and that the properly-informed common-sense of the community should temper, if not restrain, the rashness of those who, meaning to be tender, would virtually enact the most hideous cruelty by the imposition of short-sighted restrictions upon physiological investigation. It is a modern instance of zeal for God, but not according to knowledge, and an instructed public opinion must correct its excess.

And now let us cast a backward glance on the field we have traversed, and try to extract from our labors such further profit as they can yield. For more than two thousand years the attraction of light bodies by amber was the sum of human knowledge regarding electricity, and for more than two thousand years fermentation was effected without any knowledge of its cause. In science one discovery grows out of another, and cannot appear without its proper antecedent. Thus, before fermentation could be understood, the microscope had to be invented and brought to a considerable degree of perfection. Note the growth of knowledge. Leeuwenhoek, in 1680, found yeast to be a mass of floating globules, but he had no notion that the globules were alive. This was proved in 1835 by Cagniard de la Tour and Schwann. Then came the question as to the origin of such microscopic organisms, and in this connection the memoir of Pasteur, published in the "Annales de Chimie" for 1862, is epoch-making, proving as it did to all competent minds spontaneous generation to be thus far a chimera. On that investigation all Pasteur's subsequent labors were based. Ravages had over and over again occurred among French wines. There was no guarantee that they would not become acid or bitter, particularly when exported. The commerce in wines was thus restricted, and disastrous losses were often inflicted on the wine-grower. Every one of these diseases was traced to the life of an organism. Pasteur ascertained the temperature which killed these ferments of disease, proving it to be so low as to be perfectly harmless to the wine. By the simple expedient of heating the wine to a temperature of 50° centigrade, he rendered it unalterable, and thus saved his country the loss of millions. He then went on to vinegar—*vin aigre*, acid wine—which he proved to be produced by a fermentation set up by a little fungus called *Mycoderma aceti*. *Torula*, in fact, converts the grape-juice into alcohol, and *Mycoderma aceti* converts the alcohol into vinegar. Here also frequent failures occurred and severe losses were sustained. Through the operation of unknown causes, the vinegar often became unfit for use; sometimes, indeed, falling into utter putridity. It had been long known that mere exposure to the air was sufficient to destroy it. Pasteur studied all

these changes, traced them to their living causes, and showed that the permanent health of the vinegar was insured by the destruction of this life. He passed from the diseases of vinegar to the study of a malady which a dozen years ago had all but ruined the silk-husbandry of France. This malady, which received the name of *pébrine*, was the product of a parasite which first took possession of the intestinal canal of the silkworm, spread throughout its body, and filled the sack which ought to contain the viscid matter of the silk. Thus smitten, the worm would go automatically through the process of spinning when it had nothing to spin. Pasteur followed this parasitic destroyer from year to year, and, led by his singular power of combining facts with the logic of facts, discovered eventually the precise phase in the development of the insect when the disease which assailed it could with certainty be stamped out. Pasteur's devotion to this inquiry cost him dear. He restored to France her silk-husbandry, rescued thousands of her population from ruin, set the looms of Italy also to work, but emerged from his labors with one of his sides permanently paralyzed. His last investigation is embodied in a work entitled "Studies on Beer," in which he describes a method of rendering beer permanently unchangeable. That method is not so simple as those found effectual with wine and vinegar, but the principles which it involves are sure to receive extensive application at some future day. Taking into account all these labors of Pasteur, it is no exaggeration to state that the money value of his work would go far to cover the indemnity which France had to pay to Germany.

There are other reflections connected with this subject which, even were I to pass them over without remark, would sooner or later occur to every thoughtful mind in this assembly. I have spoken of the floating dust of the air, of the means of rendering it visible, and of the perfect immunity from putrefaction which accompanies the contact of moteless air. Consider the woes which this wafted matter, during historic and prehistoric ages, has inflicted on mankind; consider the loss of life in hospitals from putrefying wounds; consider the loss in places where there are plenty of wounds but no hospitals, and in the ages before hospitals were anywhere founded; consider the slaughter which has hitherto followed that of the battle-field, when those bacterial destroyers are let loose, often producing a mortality far greater than that of the battle itself; add to this the other conception that in times of epidemic disease the self-same floating matter has frequently, if not always, mingled with it the special germs which produce the epidemic, being thus enabled to sow pestilence and death over nations and continents—consider all this, and you will come with me to the conclusion that all the havoc of war, ten times multiplied, would be evanescent if compared to the ravages due to atmospheric dust.

This preventable destruction is going on to-day, and it has been permitted to go on for ages, without a whisper of information regard-

ing its cause being vouchsafed to the suffering sentient world. We have been scourged by invisible thongs, attacked from impenetrable ambuscades, and it is only to-day that the light of science is being let in upon the murderous dominion of our foes. Men of Glasgow, these facts excite in me the thought that the rule and governance of this universe are different from what we in our youth supposed them to be—that the inscrutable Power, at once terrible and beneficent, in whom we live and move and have our being and our end, is to be propitiated by means different from those usually resorted to. The first requisite toward such propitiation is *knowledge;* the second is *action*, shaped and illuminated by that knowledge. Of knowledge we already see the dawn, which will open out by-and-by to perfect day, while the action which is to follow has its unfailing source and stimulus in the moral and emotional nature of man—in his desire for personal well-being, in his sense of duty, in his compassionate sympathy with the sufferings of his fellow-men. "How often," says Dr. William Budd, in his celebrated work on "Typhoid Fever"—"how often have I seen in past days, in the single narrow chamber of the day-laborer's cottage, the father in the coffin, the mother in the sick-bed in muttering delirium, and nothing to relieve the desolation of the children but the devotion of some poor neighbor, who in too many cases paid the penalty of her kindness in becoming herself the victim of the same disorder!" From the vantage-ground already won I look forward with confident hope to the triumph of medical art over scenes of misery like that here described. The cause of the calamity being once clearly revealed, not only to the physician, but to the public, whose intelligent coöperation is absolutely essential to success, the final victory of humanity is only a question of time. We have already a foretaste of that victory in the triumphs of surgery as practised at your doors.

THE PROTECTION OF BUILDINGS FROM LIGHTNING.

By Professor J. CLERK MAXWELL.

MOST of those who have given directions for the construction of lightning-conductors have paid great attention to the upper and lower extremities of the conductor. They recommend that the upper extremity of the conductor should extend somewhat above the highest part of the building to be protected, and that it should terminate in a sharp point, and that the lower extremity should be carried as far as possible into the conducting strata of the ground, so as to "make" what telegraph engineers call "a good earth."

The electrical effect of such an arrangement is to *tap*, as it were, the gathering charge by facilitating a quiet discharge between the

atmospheric accumulation and the earth. The erection of the conductor will cause a somewhat greater number of discharges to occur at the place than would have occurred if it had not been erected; but each of these discharges will be smaller than those which would have occurred without the conductor. It is probable, also, that fewer discharges will occur in the region surrounding the conductor.

It appears to me that these arrangements are calculated rather for the benefit of the surrounding country, and for the relief of clouds laboring under an accumulation of electricity, than for the protection of the building on which the conductor is erected.

What we really wish is, to prevent the possibility of an electric discharge taking place within a certain region, say in the inside of a gunpowder-manufactory. If this is clearly laid down as our object, the method of securing it is equally clear.

An electric discharge cannot occur between two bodies, unless the difference of their potentials is sufficiently great, compared with the distance between them. If, therefore, we can keep the potentials of all bodies within a certain region equal, or nearly equal, no discharge will take place between them. We may secure this by connecting all these bodies by means of good conductors, such as copper-wire ropes, but it is not necessary to do so, for it may be shown by experiment that, if every part of the surface surrounding a certain region is at the same potential, every point within that region must be at the same potential, provided no charged body is placed within the region.

It would, therefore, be sufficient to surround our powder-mill with a conducting material, to sheathe its roof, walls, and ground-floor, with thick sheet-copper, and then no electrical effect could occur within it on account of any thunder-storm outside. There would be no need of any earth-connection. We might even place a layer of asphalt between the copper floor and the ground, so as to insulate the building. If the mill were then struck with lightning, it would remain charged for some time, and a person standing on the ground outside and touching the wall might receive a shock, but no electrical effect would be perceived inside, even on the most delicate electrometer. The potential of everything inside with respect to the earth would be suddenly raised or lowered, as the case might be, but electric potential is not a physical condition, but only a mathematical conception, so that no physical effect would be perceived.

It is, therefore, not necessary to connect large masses of metal, such as engines, tanks, etc., to the walls, if they are entirely within the building. If, however, any conductor, such as a telegraph-wire or a metallic supply-pipe for water or gas, comes into the building from without, the potential of this conductor may be different from that of the building, unless it is connected with the conducting-shell of the building. Hence the water or gas, supply-pipes, if any enter the building, must be connected to the system of lightning-conduct-

ors, and, since to connect a telegraph-wire with the conductor would render the telegraph useless, no telegraph from without should be allowed to enter a powder-mill, though there may be electric bells and other telegraphic apparatus entirely within the building.

I have supposed the powder-mill to be entirely sheathed in thick sheet-copper. This, however, is by no means necessary in order to prevent any sensible electrical effect taking place within it, supposing it struck by lightning. It is quite sufficient to inclose the building with a network of a good conducting substance. For instance, if a copper wire, say No. 4, B. W. G. (0.238 inch diameter), were carried round the foundation of the house, up each of the corners and gables and along the ridges, this would probably be a sufficient protection for an ordinary building against any thunder-storm in this climate. The copper wire may be built into the wall to prevent theft, but should be connected to any outside metal, such as lead or zinc on the roof, and to metal rain-water pipes. In the case of a powder-mill it might be advisable to make the network closer by carrying one or two additional wires over the roof and down the walls to the wire at the foundation. If there are water or gas pipes which enter the building from without, these must be connected with the system of conducting-wires, but, if there are no such metallic connections with distant points, it is not necessary to take any pains to facilitate the escape of the electricity into the earth.

Still less is it advisable to erect a tall conductor with a sharp point in order to relieve the thunder-clouds of their charge.

It is hardly necessary to add that it is not advisable, during a thunder-storm, to stand on the roof of a house so protected, or to stand on the ground outside and lean against the wall.—*Nature.*

MORMONISM FROM A MORMON POINT OF VIEW.

By DANIEL WEDDERBURN.

DURING a recent visit to Salt Lake City I happened to ask one of the leading Mormons what works, in addition to the Book of Mormon, would give me a fair idea of the religious doctrines professed by the Latter-day Saints and of their history, as they themselves desire to have it told. The gentleman addressed most kindly offered for my acceptance several books, among which were pamphlets by Orson Pratt, one of the twelve apostles of the church, the "Key to the Science of Theology," by Parley P. Pratt, and the "Rise, Progress, and Travels of the Church of Jesus Christ of Latter-day Saints," by President George A. Smith.

So far as religious tenets are concerned, the authority of the works

mentioned may doubtless be accepted as final. With regard to the historical portion of the subject it is different, and here a certain allowance must be made for the bias of a religious partisan; but it is not the less interesting to read this brief but stirring history, as it is told by those who played a prominent part in its events. Having studied these books, I shall endeavor to give a short account of Mormonism, as it is described by the Mormons themselves, and as it appears to myself, being personally little predisposed to regard it favorably, but convinced that its case has seldom been fairly stated to the public.

A certain practical importance attaches at present to the subject, for the future position of Mormonism in the Union is among the many difficult political problems now offering themselves for solution in the United States of America. It presents, indeed, upon a small scale, a similar difficulty to that caused by the existence of slavery in the Southern States: as to how far it is possible to maintain political federation between communities differing essentially in their social institutions. The American Constitution is wonderfully elastic, but it has proved impossible to retain slaveholding States permanently within its limits. Is its elasticity sufficient to admit into the Union a State which would legalize polygamy? Hitherto a negative answer has been given by Congress to this question, and the claims of Utah Territory to become a State have been urged in vain; but the steady increase of population and wealth is constantly strengthening those claims, and they cannot much longer be ignored. The fourth unsuccessful attempt to obtain admission as a State of the Union was made in 1872, when the population of Utah already exceeded that of Nevada and Nebraska combined (at the date of their admission), being upward of 105,000; and a memorial to Congress was adopted, praying for admission into the Union as a sovereign State. The constitution then proposed for the State, which was to bear the name of Deseret, was approved by the people of the Territory, with only 368 dissentient votes; it provided for women's suffrage, and minority representation.

The admission of Nevada, Nebraska, and Colorado, all of them neighboring Territories with inferior population to Utah, appears to justify the assertion of the Mormons that the unpopularity of their religion was the sole cause of their exclusion. Had Deseret been created a sovereign State in 1872, the controversy as to polygamy might have entered upon a new and critical phase, as the State Legislature would doubtless have claimed the right to legalize plurality of wives within its own jurisdiction. No such right can be claimed by the existing Legislature of Utah, whose powers are restricted by the provisions of the act of 1850, to which the Territory owes its political existence. All laws of the Territorial Legislature must have the sanction of the Governor (who is appointed by the President of the

United States), and are passed subject to the approval of Congress. The judges of the Territorial Supreme Court are also appointed by the President, so that the control of the Federal authorities is complete over all departments in the Territory, and it is natural that the Mormon community should aspire to a more independent position. It is questionable, however, whether independence would not prove a disadvantage to the Mormons, as tending to bring them into direct collision with popular feeling, which has always been more or less hostile to them throughout the Union, while the Federal authorities have acted a friendly part. During seventeen sessions of the Utah Legislative Assembly, the power of disapproval has only once been exercised by Congress, and then (as might have been expected) in relation to the law of marriage. The Washington Government has afforded protection to the Mormons against local officers and judges, President Grant, in particular, having recently braved considerable unpopularity by removing the Chief-Justice of the Supreme Court of Utah for "arbitrary and illegal conduct" in his dealings with the Latter-day Saints. Again, a few years ago the United States officials in Utah set at naught the Territorial law under which jurors were selected and summoned, rejecting those who professed their belief in Mormon doctrines. Where the value at issue exceeds $1,000, an appeal lies to the Supreme Court of the United States, and a case tried by a packed jury, and given against the municipal officers of Salt Lake City, was accordingly appealed. The unanimous decision of the Supreme Court at Washington was, that the jury had not been legally impaneled, and the judgment of the Utah court was reversed. Great rejoicing was caused at Salt Lake City by this decision in the Engelbrecht case, as proving that the inhabitants of Territories had rights in common with their countrymen, and that there was justice in the United States even for the professors of a very unpopular religion.

It may appear strange that in the freest of lands, and in the latter half of the nineteenth century, a legal doubt should have existed as to whether civil disabilities were attached to any form of religious opinion; but it must be remembered that the evidence of an atheist was very recently rejected in English courts of justice, and the Legislature of North Carolina expelled last year a member, because he conscientiously declared his disbelief in the existence of God. The fact is that, even in Protestant countries, complete religious toleration is limited to certain recognized persuasions, so that feeble and unpopular sects have still to unite in claiming for themselves the same liberty of conscience which has been conceded to all numerous and powerful dissenting bodies. Science now demands from theology absolute and unconditional freedom, and the day can hardly be far distant when theological heterodoxy will cease to involve any civil penalties in a free country. At present the Mormon refugees of the

Rocky Mountains demand only that amount of civil and religious liberty which the Constitution professes to guarantee to every American citizen, and which the Pilgrim Fathers found for themselves "on the wild New England shore." They complain that their enemies have told their story, that their own statements have been ignored, and that no credit has been given to them for an honest attempt, in these latter days, to put in practice the doctrines of the early Christian Church. Even their enemies will hardly deny that they displayed faith, courage, and endurance, when they resolved, after being expelled from one settlement after another, to plunge into the unknown wilderness, and to found a new Zion beyond the existing limits of the United States. These qualities have triumphed over great physical difficulties, and a stranger is astonished at the prosperity which Mormon industry has produced. A carefully-organized system of irrigation has converted a barren desert into a productive garden, and has had the remarkable effect of raising the permanent level of the lake ten feet higher than it was in 1850. Every requirement of the religious community is abundantly supplied by contributions, assessed and collected upon voluntary principles. Besides the immense new Tabernacle, a temple is now in course of construction, almost Egyptian in its massive grandeur, toward which all the faithful contribute, those who cannot afford money giving their labor. The Indians in Utah have been conciliated by the humane policy of feeding, clothing, and teaching, instead of fighting them. The old accusations of violence and cruelty toward Gentile immigrants, or Mormon deserters, if not altogether disproved, have at least been lived down in recent times, and the existence of a military camp near Salt Lake City is now, probably, more unnecessary than it would be at any other town west of the Rocky Mountains. In order to appreciate the tranquillity, sobriety, and steady industry of Deseret (as the Mormons prefer to name their country), it may be contrasted with N vada, an adjoining State almost identical with Deseret as to soil, climate, and mineral products. The so-called Silver State stands now preëminent in the Union for its turbulent manners, for the number of its liquor-shops, and as being the only State which legalizes public gambling. Of course, Nevada is merely passing through a certain rude stage of her existence, just as California had done before her, and she, too, will one day set her house in order; the remarkable point is that Utah should, alone among the young communities of the far West, have altogether escaped such a condition of things. To many persons this will appear to be sufficiently explained by the fact that the Mormons both preach and practise habits of extreme temperance, almost amounting to total abstinence from every sort of stimulant.

Considerable hostility undoubtedly exists between the Mormons and some of their Gentile fellow-residents; this is greatly due to the bitter attacks of certain local newspapers upon the Latter-day Saints,

and upon those who show them any favor. When I was in Salt Lake City, the Governor of Utah Territory was very severely assailed for his alleged partiality toward the Mormons, and a grim hope was at the same time expressed that Mr. Brigham Young might shortly take the place merited by him "at the only fireside, which we know of, large enough to accommodate him and the whole of his family." That such expressions are publicly used in speaking of a man whom the great bulk of the community regard as an inspired prophet, is a sufficient proof that no terrorism is now exercised against dissenters from the dominant church of Utah. To a stranger like myself, desirous of understanding as far as possible the tenets of their faith, a frank and friendly reception was accorded by such of the Mormon leaders as I had an opportunity of visiting. Every explanation asked for was at once afforded, but I do not feel justified in mentioning names, or in repeating any private conversation, although it was probably not intended to be confidential. A passing stranger can only see the external surface of society, and in this respect there is nothing very remarkable in Salt Lake City. The parlor of a flourishing Mormon householder does not differ much in appearance from that of an Englishman who happens to have a numerous family, with a large proportion of sisters or daughters. A new and somewhat startling sensation is, however, experienced during the ceremony of introduction on first hearing the words, "Now, sir, let me introduce you to another of my wives." The strangeness of these words mainly consists in the very fact that they are uttered, not by a dark-skinned barbarian, but by a gentleman answering to the description of the English soldiers given by "Le Conscrit de 1813"—"blancs, bien rasés, comme de bons bourgeois"—and in a room with all the familiar surroundings of civilized domestic life. The public worship of the Church of Jesus Christ of Latter-day Saints, as the Mormons invariably designate their own sect, is conducted with great simplicity, very much as it is in an English dissenting chapel, and the preponderance of ladies is by no means greater than that to which we are accustomed in places of worship generally. The only marked peculiarity is the administration of the Lord's Supper in water instead of wine, and of this sacrament it appears to be customary for all the faithful present to partake, old and young alike. The hymns are sung by a mixed choir of young men and women, and addresses are delivered by eminent Mormon elders. When I was present, the speakers were Mr. Daniel H. Wells, Mayor of Salt Lake City, and Mr. Cannon, brother of the delegate from Utah Territory to Congress. All religious argument was based upon the authority of the Bible, to which the Mormon revelations claim to be *additional*, but in no sense *contrary*. Various Mormon doctrines were touched upon, and special allusions were made to the persecutions undergone by the Saints in past times, and to those which appeared to menace them in the future. Although not

yet half a century old, the Church of Jesus Christ of Latter-day Saints has passed through a baptism of fire, and living men can speak with mingled pride and sorrow of personal friends who died as martyrs to their religious faith. Thirty years ago Nauvoo, in Illinois, was a Mormon settlement, almost equal in population and prosperity to Salt Lake City at the present day; those who witnessed its total destruction can hardly be considered idle alarmists, when they allude to the possibility of trials yet to come. The tone of the speakers was thoroughly practical, exhorting to industry and sobriety, to abstention from all stimulants, including tobacco, coffee, and tea, and to the cultivation of all the useful arts, "even those of war, if necessary to the safety of our community." These exhortations were mainly addressed to the juniors present, a saving clause being inserted for those seniors who had borne the burden and heat of the evil days, and who, having now established this mountain refuge for the Saints, might require to "solace decaying nature" with an occasional narcotic. The addresses breathed a tolerant and rational spirit, the doctrines inculcated were simply those of a charitable form of Christianity, and there was no mention of that peculiar domestic institution which sums up in the minds of so many all notions connected with Mormonism.

After all, it is upon "plural marriages" that the interest as well as the hostility of the outer world has always been concentrated; a Mormon is simply regarded as a man with a number of wives, and beyond this most people know little, and care less, as to the doctrines or customs of the Latter-day Saints. Were it not for their polygamy, it seems probable that the Mormons might now enjoy the same perfect toleration which is extended in America to other forms of religious eccentricity, and that Deseret would long ere this have taken her place among the States of the Union. On the other hand, it must be borne in mind that polygamy is a comparatively recent innovation, condemned by the Book of Mormon in the strongest possible terms:

"The word of God burdens me because of your grosser crimes. For behold, thus saith the Lord, this people (the Nephites) begin to wax in iniquity; they understand not the Scriptures; for they seek to excuse themselves because of the things which were written concerning David and Solomon his son. Behold, David and Solomon truly had many wives and concubines, which thing was abominable before me, saith the Lord; wherefore, thus saith the Lord, I have led this people forth out of the land of Jerusalem, by the power of mine arm, that I might raise up unto me a righteous branch from the fruit of the loins of Joseph. Wherefore I, the Lord God, will not suffer that this people shall do like unto them of old. Wherefore, my brethren, hear me, and hearken to the word of the Lord; for there shall not any man among you have save it be one wife, and concubines he shall have none; for I, the Lord God, delighteth (*sic*) in the chastity of women."

These are the words of "Jacob, the brother of Nephi," and words could hardly be more distinct or emphatic; but theologians can generally manage to explain away inconvenient texts and hard sayings, while in this case it may be held by the Saints that the above injunctions were repealed by the subsequent "Revelation on Celestial Marriage." This tardy revelation, vouchsafed to Joseph Smith shortly before the close of his career, is the sole warrant for plurality of wives —a practice which is general among the Mormon leaders, but not throughout the community at large. With them, as with Mohammedans or Hindoos, polygamy is doubtless very much a question of expense, and I was informed on good authority that probably about one in four of the Saints is the husband of more than one wife. The majority, therefore, adheres in practice to the "Doctrine and Covenants," which book is a recognized authority upon articles of Mormon faith, and declares that "one man should have one wife, and one woman but one husband, except in case of death, when either is at liberty to marry again." The number of wives ascribed to eminent individuals is usually exaggerated, sixteen being the largest number admittedly married to one man, and six constituting the household of a wealthy and influential elder.

The Mormons compare themselves to the Jews, as well as to the early Christians; they have been a persecuted people, driven forth to wander through trackless deserts, and are now living apart from their neighbors in a theocratic commonwealth of their own. Their precedents on behalf of polygamy are mainly drawn from the Hebrew Scriptures; but they also assert that they have in their favor the example of the primitive Christian Church. Without going into their arguments, it may be at once conceded that polygamy was sanctioned by the ancient Hebrew law; but it is not the less out of date in the new world of America, and is a standing peril to the Church of the Latter-day Saints. By an act of the Utah Legislature, the right of suffrage has been conferred on "all American women, native or naturalized," and it hardly seems possible that polygamy can long survive such legislation. At present the extension of the franchise among persons, few of whom are "native" Americans, and many of whom are very imperfectly educated, probably strengthens the hands of the Mormon leaders by swamping entirely the Gentile element. But such an effect is not likely to be permanent, for the rising generation will be educated; in 1871, just after the passing of the act above referred to, sixty per cent. of the girls between four and sixteen years of age were enrolled as scholars throughout Utah Territory, being slightly in excess of the percentage among boys of the same age. Equality between the sexes in education and in electoral privileges must tend to bring about social and religious equality also, and the example of their independent sisters in Wyoming Territory, where women enjoy complete civil rights, will not be thrown away upon the ladies of Salt

Lake City. The tone of public feeling throughout the neighboring States and Territories is more favorable toward "woman's rights" than it is in any other part of the world; and, even if this be partly due to a reaction produced by Mormonism, it cannot fail in time to influence the female electors of Utah. Thus it is possible that a peaceable solution of the difficulty may be found, and polygamy may be abolished, not by external force, but by constitutional action within the Mormon community itself.

Meanwhile, this church of the nineteenth century possesses amazing vitality, and seems to carry us back to a by-gone era of belief, exhibiting as it does the phenomenon of a religious sect heartily convinced of its future mission and claiming the present for its own. While other churches look to the past for all that is best and truest in religion, the Latter-day Saints regard the present also as a period of miracle and revelation. They expect, in the immediate future, the conversion of all who inhabit their vast continent with as serene a confidence as that with which the early Christians seem to have anticipated the evangelization of the Roman Empire. It may be said of them that in theology they maintain the modern doctrine of continuity, rather than ancient theories of convulsion and catastrophe. Accepting, in a literal sense, the Jewish and Christian Scriptures, they apparently entertain no fear lest scientific research should undermine their faith, as they look for a continuous course of revelation, which shall harmonize theology with the general advance in human knowledge.

The title of Parley P. Pratt's recent work, "Key to the Science of Theology," 1874, may seem almost to involve a contradiction in terms; but it indicates the desire of a distinguished Mormon theologian to keep abreast, if possible, of the scientific spirit of the age. Whether the attempt to do this may have proved successful or not, his policy is surely wiser than that which has frequently placed science and theology in opposition so direct, that every conquest of knowledge over ignorance has appeared to be also a victory over religion. Indeed, Mr. Parley Pratt is entitled to a welcome from the lovers of free thought, considering how rarely theologians seek to identify the progress of their own tenets with that of humanity in every department of science and art, and how seldom it is that they do not

> "Grow pale
> Lest their own judgments should become too bright,
> And their free thoughts be crimes, and earth have too much light."

To quote his own words:

"The creeds of the Fathers seem to have been cast in the mould of other ages, to be adapted to a more narrow sphere of intellectual development, and to be composed of material too much resembling cast-iron; or, at least, not sufficiently elastic to expand with the expansion of mind, to grow with the growth, and advance with the progressive principles of the age. For these reasons, per-

haps more than any other, the master-spirits of the age are breaking loose from the old moorings, and withdrawing from established and venerated systems."

Holding these views, Mr. Parley Pratt has aimed at embodying, in his introductory key, a general view of what he calls the Science of Theology, "in a concise and somewhat original manner and style, as gathered from revelation, history, prophecy, reason, and analogy." The revelation and prophecy referred to and founded upon are partly those accepted by all orthodox Christians, partly those of recent date (such as the Book of Mormon and the Doctrine and Covenants) peculiar to the followers of Joseph Smith. It is hard to reconcile polygamy with "the progressive principles of the age," and with modern ideas as to the social position and dignity of woman; but Mr. Parley Pratt is not without a scientific plea on behalf of his theological dogma. He maintains that—

"The principal object contemplated by this law is the multiplication of the children of good and worthy fathers, who will teach them the truth, and this is far preferable to sending them into the world in the lineage of an unworthy or ignorant parentage. . . . A wise legislation, or the law of God, would punish with just severity the crimes of adultery or fornication, and would not suffer the idiot, the confirmed, irreclaimable drunkard, the man of hereditary disease, or of vicious habits, to possess or retain a wife; while at the same time it would provide for a good and capable man to honorably receive and entertain more wives than one. . . . The restoration of pure laws and practices has already commenced to improve or regenerate a race. A holy and temperate life; pure morals and manners; faith, hope, charity; cheerfulness, gentleness, integrity; intellectual development, pure truth, and knowledge, will produce a race more beautiful in form and features, stronger and more vigorous in constitution, happier in temperament and disposition, more intellectual, less vicious, and better prepared for long life and good days in their mortal sojourn. Each generation governed by the same laws will still improve."

This sounds plausible enough in theory, and perhaps the result of polygamy as practised in Utah is, that a large proportion of offspring is born to the most energetic, intelligent, and industrious citizens. In an age when there is reason to fear an increasing tendency to "non-survival of the fittest," such a result may be admitted as tending to counterbalance some of the disadvantages attending plurality of wives.

The highest types of domestic animals have been developed under a system of breeding and selection, very similar to that which is advocated in the above quotations, and the burden of proof seems to rest upon those who maintain that a high type of humanity cannot be developed after a similar fashion. Should the Mormons succeed in carrying out practically, for a few generations, any such ideas as are above alleged to be the main objects contemplated in their law of polygamy, they would have fair grounds for the belief that they are destined to inherit the whole earth.

A race of human beings developed (if such a thing were feasible) by strictly scientific selection and culture could not fail to gain the upper hand in the general struggle for dominion, but it remains to be seen whether any success in this direction will attend the system of the Mormons.

"Our physical organization, health, vigor, strength of body, intellectual faculties, inclinations, etc., are influenced very much by parentage. Hereditary disease, idiocy, weakness of mind or of constitution, deformity, tendency to violent and ungovernable passions, vicious appetites and desires, are engendered by parents, and are bequeathed as a heritage from generation to generation."

These are the words of a leading apologist of polygamy, who founds an argument in his own favor upon this truth, now generally admitted, but almost as generally ignored. It is impossible here to discuss so wide and so difficult a question, and I must limit myself to these few brief quotations from the "Key to the Science of Theology," leaving the reader to judge of their worth.

The series of pamphlets by Orson Pratt contains discussions on a great variety of questions connected with Mormonism. In particular the "Divine Authenticity of the Book of Mormon" is considered at great length, as well as the question, "Was Joseph Smith sent of God?"

Mr. Orson Pratt endeavors to show, in the first place, that to expect more revelation is not *unscriptural;* secondly, that it is not *unreasonable;* and, thirdly, that it is *indispensably necessary.* He then goes on to compare the evidences of the Book of Mormon and of the Bible, alleging that both alike have been confirmed by miracles, and that the prophecies of the Bible, especially those of Isaiah, have been fulfilled in the Book of Mormon and in the history of Mormonism. Throughout his elaborate arguments he assumes the genuineness and authenticity of the Bible, an assumption which he is of course entitled to make in arguing with orthodox Christians. His position is: The truth of the Bible rests upon sufficient evidence, and this evidence is in every way weaker than that which can be adduced for the Book of Mormon—therefore, *a fortiori*, the Book of Mormon is true. Whatever may be the flaw in this syllogism, those whom Archdeacon Paley satisfies cannot fail to have some trouble in disposing of Mr. Orson Pratt. Toward other Christian sects, whose creeds "are an abomination unto the Lord," the Mormon apostle displays but little brotherly feeling. Upon papist and Protestant alike he pours out the vial of his wrath and contempt in language almost too forcible for quotation; but he seeks to base every reproach directed against them upon texts from the orthodox Scriptures. The pamphlet entitled "The Bible and Tradition, without Further Revelation, an Insufficient Guide," is, in fact, a powerful onslaught upon modern Christendom, perhaps as damaging as any that a professed unbeliever could

have made, although in this case the assailant accepts with reverence the Christian Scriptures, seeking to found thereon a revelation newer and more complete.

It is somewhat disappointing, if the Book of Mormon is to be accepted as the new revelation, to find it so very inferior, alike in matter and in style, to its great predecessors. Nearly equal in bulk to the Old Testament, it lacks altogether the poetic grandeur and the graphic force of the Hebrew Scriptures, although the Biblical phraseology has been laboriously imitated throughout. It is styled "An Account written by the Hand of Mormon upon Plates taken from the Plates of Nephi. Translated by Joseph Smith, Jr.:"

"Wherefore it is an abridgment of the record of the people of Nephi, and also of the Lamanites; written to the Lamanites, who are a remnant of the house of Israel; and also to Jew and Gentile; written by way of commandment, and also by the spirit of prophecy and of revelation. Written and sealed up, and hid up unto the Lord, that they might not be destroyed; to come forth by the gift and power of God unto the interpretation thereof: sealed by the hand of Moroni, and hid up unto the Lord, to come forth in due time by the hand of Gentile; the interpretation thereof by the gift of God.

"An abridgment taken from the Book of Ether also; which is a record of the people of Jared; who were scattered at the time the Lord confounded the language of the people when they were building a tower to get to heaven; which is to show unto the remnant of the house of Israel what great things the Lord hath done for their fathers; and that they may know the covenants of the Lord, that they are not cast off forever; and also to the convincing of the Jew and Gentile, that JESUS is the CHRIST, the ETERNAL GOD, manifesting himself unto all nations. And now if there are faults, they are the mistakes of men; wherefore condemn not the things of God, that ye may be found spotless at the judgment-seat of Christ."

The sacred volume is divided into thirteen books, bearing the names of various prophets, one of whom is Mormon. The last book is that of Moroni, who says:

"Behold I, Moroni, do finish the record of my father, Mormon. Behold, I have but few things to write, which things I have been commanded by my father. And now it came to pass that, after the great and tremendous battle at Cumorah, behold, the Nephites, who had escaped into the country southward, were hunted by the Lamanites, until they were all destroyed; and my father also was killed by them, and I even remained alone to write the sad tale of the destruction of my people. But, behold, they are gone, and I fulfill the commandment of my father. And whether they will slay me, I know not; therefore I will write and hide up the records in the earth, and whither I go it mattereth not. Behold my father hath made this record, and he hath written the intent thereof. And behold, I would write it also, if I had room upon the plates; but I have not; and ore I have none, for I am alone; my father hath been slain in battle, and all my kinsfolks, and I have not friends, nor whither to go; and how long the Lord will suffer that I may live I know not. Behold, four hundred years have passed away since the coming of our Lord and Saviour.

"And now, behold, we have written this record according to our knowledge

in the characters which are called among us the reformed Egyptian, being handed down and altered by us, according to our manner of speech. And if our plates had been sufficiently large, we should have written in Hebrew; but the Hebrew hath been altered by us also; and if we could have written in Hebrew, behold, ye would have had no imperfection in our record. But the Lord knoweth the things which we have written, and also that none other people knoweth our language, therefore he hath prepared means for the interpretation thereof. And these things are written, that we may rid our garments of the blood of our brethren, who have dwindled in unbelief. And behold, these things which we have desired concerning our brethren, yea, even their restoration to the knowledge of Christ, is according to the prayers of all the saints who have dwelt in the land. And may the Lord Jesus Christ grant that their prayers may be answered according to their faith; and may God the Father remember the covenant which he hath made with the house of Israel; and may he bless them forever, through faith on the name of Jesus Christ! Amen."

The record in question professes to contain a history of the American Continent from the date of its first colonization by Jared and his brother at the time of the dispersion from Babel down to the year A. D. 420, when Moroni, the last of the Nephite prophets, buried his plates in the hill of Cumorah. This account of prehistoric America is but a tedious composition, full of battles and slaughter, full of proper names, of reiterations, and of unnecessary phrases. We are told how the Jaredites, emigrants from the valley of Nimrod, who "did carry with them Deseret, which by interpretation is a honey-bee," attained to great civilization and prosperity in North America, and were utterly destroyed by internecine warfare about the year 600 B. C. They were succeeded by a "remnant of the house of Joseph," brought from Jerusalem in the reign of Zedekiah to inherit the land. These appear to have crossed the Pacific Ocean, landing on the west coast of South America, whence they eventually overspread that continent. They separated before long into two distinct nations, known as Nephites and Lamanites, the former migrating from the persecutions of the latter, and sailing "forth into the west sea by the narrow neck which led into the land northward." Through the personal ministry of Jesus Christ, who visited them shortly after his ascension, the Nephites were converted from the Mosaic to the Christian faith, which was in time accepted by the Lamanites also; and for two hundred years they prospered and multiplied, and there was no contention in the land, all things being common among them. This golden age was succeeded by a period of apostasy; "and from that time forth they did have their goods and their substance no more common among them, and they began to be divided into classes, and they began to build up churches unto themselves, to get gain, and began to deny the true church of Christ." A terrible war broke out between the Nephites, now settled in North America (known as the land Desolation), and the Lamanites, who invaded them from the land Bountiful,

lying southward of the Isthmus of Darien. This war ended in the annihilation of the Nephites, "an exceeding fair and delightsome people," while a degraded remnant of the Lamanites still survive, after fifteen centuries of rapine and discord, under the name of American Indians. "Now the heads of the Lamanites were shorn; and they were naked, save it were skin, which was girded about their loins; and the skins of the Lamanites were dark, according to the mark which was set upon their fathers, which was a curse upon them because of their transgression." Thus the term *Gentile* is properly used to denote the *white man*, as distinguished from the copper-colored house of Israel, and the Mormons themselves are expressly described as the "Gentile Saints." For the remnant of Joseph a glorious future is prophesied. They, the despised redskins, shall have the land for their inheritance, and it shall be "a land of liberty unto the Gentiles, and there shall be no kings upon the land." They are to be the chief agents in building the New Jerusalem, and will be converted and redeemed before their brethren of Judah.

The story of the plates, from which the sacred book is said to have been translated, first into English, and subsequently into nearly all the European languages, is of some interest from an archæological point of view, and may be told in a few words. They are described as having been found by Joseph Smith in a cyst composed of six stones, smooth on the inner surfaces, and firmly cemented together. This stone box was buried in the side of a hill near Palmyra, in the State of New York. The plates had the appearance of gold, were six by eight inches in width and length, each plate being nearly as thick as common tin. They were filled on both sides with small characters beautifully engraved, and were fastened at one edge with three rings running through the whole: thus bound together they formed a volume about six inches in thickness, a part of which was sealed. Various unsuccessful attempts were made by the enemies of Joseph Smith to obtain possession of these plates, and they finally disappeared, having been examined and described by eleven persons, whose testimony, signed with their names, is added to the Book of Mormon.

The evidence of these persons would have been more conclusive had not all of them been believers in the new prophet; moreover, the disappearance of the plates is not quite satisfactorily explained by the statement that they were restored to the charge of the angel under whose guidance they were discovered. Still the actual existence, as well as the genuine antiquity, of plates such as Joseph Smith is said to have brought to light in 1827, seems to have been sufficiently verified elsewhere.

In 1843, near Kinderhook, Illinois, in excavating a large mound, six brass plates were discovered, of a bell-shape, four inches in length, and covered with ancient characters. They were fastened together

with two iron wires, almost entirely corroded, and were found, along with charcoal, ashes, and human bones, more than twelve feet below the surface of a mound of the sugar-loaf form common in the Mississippi Valley. Large trees growing upon these artificial mounds attest their great antiquity, and doubtless they contain much that will reward future investigation. No key has yet been discovered for the interpretation of the engravings upon these brass plates, or of the strange glyphs upon the ruins of Otolum, in Mexico; but when an amount of talent, learning, and labor, equal to that bestowed upon Egyptian hieroglyphics or Assyrian cuneiform characters, has been devoted to American antiquities, we may hope to learn something of those mysterious races whose history the Book of Mormon professes to tell.

But if we admit that the plates themselves may have been genuine, our faith in the founder of Mormonism, as a sincere religious enthusiast, is staggered by his mode of interpreting their contents. He tells us that he found along with the records an instrument, called by him the Urim and Thummim, and described as consisting of "two transparent stones set in the rim of a bow." Through the medium of this instrument, he says that he translated the unsealed portion of these scanty records, the result being a bulky volume in English, but he does not explain whether he used it as a magnifier, nor how it proved to be a Rosetta stone for his hieroglyphics, merely asserting that it was "by the gift and power of God." That Joseph Smith believed in his own mission, his character and career alike appear to indicate, and the many ecstatic visions which he describes were probably real enough to him, but the compilation of the Book of Mormon was an act involving much time and labor, and cannot be accounted for by ecstasy.

In these days of La-Salette and Paray-le-Monial it is, perhaps, too much to say that a miracle, in order to find acceptance among educated persons, must be relegated to a remote age and country, and must be invested with a certain amount of external dignity. It is, however, a severe test of faith to be called upon to accept miracles and revelations from a prophet well known to men yet living as "Joe Smith," and referred to as "Mr. S." in the writings of so eminent a disciple as Mr. Orson Pratt. A most remarkable man Mr. S. undoubtedly was, capable of inspiring alike *inestinguibil odio, ed indomato amor.* The bitter hostility of his opponents was more than equaled by the devoted zeal of his converts, and, although murdered by mob violence at the early age of thirty-eight, he had already so well accomplished his work that the new creed, instead of dying with him, continued to spread with increasing rapidity, and was preached by his apostles and elders in every quarter of the globe. He was a New-Englander, born A. D. 1805, in the State of Vermont, and began to have visions when he was about fourteen years of age. In 1830

the Church of Jesus Christ of Latter-day Saints was first organized at Fayette, in the State of New York, and its headquarters were moved gradually westward, until a considerable settlement was formed in Jackson County, Missouri. Here it was expected that the New Jerusalem would be built, but an organized system of persecution drove the Saints out of the State of Missouri, and in 1839 they took refuge in Illinois, where they built the city of Nauvoo, in Hancock County, on the banks of the Mississippi, and enjoyed a short respite from persecution. But in 1844 popular hostility broke out with increased violence, and Joseph Smith (who had been frequently brought before judicial tribunals, and invariably acquitted) proceeded with his brother Hyrum to Carthage, where they surrendered themselves prisoners on a charge of treason, the Governor of Illinois having promised them protection and a fair trial. On the 27th of June, 1844, a large body of men, with their faces blackened, surrounded the prison, and murdered the two brothers Smith. Several of these men were indicted for murder, and were tried about a year later, but they were acquitted. The persecution of the Mormons did not slacken after the death of their prophet, and in September, 1845, an armed mob commenced burning houses in Hancock County, while the authorities declared that the State was unable to protect the Mormons, and they must therefore go. Preparations were made by Brigham Young, President of the Twelve Apostles, and the other leaders of the church, to explore the Rocky Mountains in accordance with an expressed intention of the deceased prophet, and in February, 1846, the exodus of the Mormons commenced. It was not, however, rapid enough to satisfy their enemies, and in September the city of Nauvoo was burned by an armed mob, after several days' siege, and the remnant of the Mormons was driven across the Mississippi into Iowa. In the spring of 1847 Brigham Young, with a party of pioneers, started from his winter-quarters on the Missouri in search of a place of settlement. On the 24th of July he reached the Great Salt Lake Valley, after a laborious march of more than one thousand miles through an unexplored country. After erecting a fort, and hoisting the stars and stripes upon what was then Mexican territory, President Young hastened back to the banks of the Missouri, and in the fall of 1848 he arrived once more in Salt Lake Valley, with eight hundred wagons, and the main body of the Mormons. The severest hardships were undergone by these people, not only during their march, but during the first two years after settling in this barren valley, four thousand three hundred feet above the sea, but strict discipline was enforced in the camp, and a careful system of rationing was maintained, until an abundant harvest at last put an end to the necessity. In 1850 the Territorial government of Utah was organized by act of Congress, and Brigham Young was appointed Governor by the President of the United States. From that time forward the

new colony has continued to prosper and progress with almost unexampled rapidity, in spite of great disadvantages as to soil, climate, and situation.

There are few countries on the face of the globe where the Latter-day Saints have not attempted to preach their gospel, but as a rule their preaching has not been tolerated. The records of their missionary efforts make it obvious enough why they obtain so large a proportion of their converts from Great Britain and Denmark, while so few come from the Roman Catholic countries of Europe; except in Scandinavia and the British Empire, the foreign missions of the Mormons have failed through the opposition of the powers that be, who have not only prohibited the missionaries from preaching, but in many cases have expelled them from the country. Even in Norway, so bitterly hostile were the ecclesiastics as to decide that the Church of Jesus Christ of Latter-day Saints is not a *Christian* sect, in order to deprive it of the protection guaranteed by Norwegian law to all Christian dissenters. Three paragraphs from the Mormon Creed, as stated by Joseph Smith himself, will show the injustice of such a decision:

"We believe in God, the Eternal Father, and in His Son, Jesus Christ, and in the Holy Ghost. We believe that through the atonement of Christ all mankind may be saved by obedience to the laws and ordinances of the Gospel. We believe that these ordinances are: First, Faith in the Lord Jesus Christ; second, Repentance; third, Baptism by immersion for the remission of sins; fourth, Laying on of hands for the Gift of the Holy Ghost."

It is supposed that a larger percentage of the Danes than of any other nation has hitherto embraced Mormonism, and a Danish newspaper is regularly published at Salt Lake City. Since the separation of Schleswig-Holstein from Denmark, the recruiting-ground of the Mormons has been reduced, as their preaching has been rigidly suppressed in those duchies. Of late years the immigration into Utah from the European missions has varied from one to four thousand persons annually. The most active attempts at propagandism appear to have been made about the years 1852–'53, but in this country a Mormon mission was founded as early as 1837, six years before the "Revelation on Celestial Marriage" had given its peculiar character to Mormonism.

It was not until 1843, thirteen years subsequent to the publication of the Book of Mormon, and to the first organization of the Church of Latter-day Saints, that Joseph Smith proclaimed this new and startling revelation. The style of the document resembles that of the Book of Mormon, but it reveals "a new and an everlasting covenant," distinctly at variance with the teachings of that book already quoted, and justifies the patriarchs, and David and Solomon, "as touching the principle and doctrine of their having many wives." It is addressed

to "my servant Joseph," and confers upon him "the keys and power of the priesthood: And verily, verily I say unto you, that whatsoever you seal on earth, shall be sealed in heaven." Upon "mine handmaid, Emma Smith, your wife," on the other hand, obedience and submission are inculcated in the strongest terms. She is required to "receive all those that have been given unto my servant Joseph—And I command mine handmaid, Emma Smith, to abide and cleave unto my servant Joseph, and to none else. But if she will not abide this commandment she shall be destroyed, saith the Lord." The revelation contains twenty-five short paragraphs only; it is somewhat apologetic in general tone, and is full of scriptural quotations and precedents. A considerate stipulation is made for the consent of the first bride, when another is to be espoused: "As pertaining to the law of the priesthood: If any man espouse a virgin, and desire to espouse another, and the first give her consent; and if he espouse the second, and they are virgins, and have vowed to no other man, then is he justified." A marriage contracted under the new covenant, and sealed by the appointed authority, is valid to all eternity, whereas in the case of ordinary married persons death terminates the contract, and for them in heaven there will be neither marrying nor giving in marriage.

Such are the terms of Joseph Smith's "Revelation of Celestial Marriage," which reminds one of the convenient doctrines from time to time revealed to Mohammed upon analogous subjects. One more revelation and prophecy remains to be noticed; it is said to have appeared in the "Pearl of Great Price," published at Liverpool in 1851, and to have been "given by the prophet, seer, and revelator, Joseph Smith," on Christmas-day, 1832. The date of publication is the point requiring verification, and a genuine copy of the pamphlet above named would be invaluable, as the language of the alleged prophecy has no prophetic ambiguity, and the fulfillment has been complete. In a few terse words are described the rebellion of South Carolina, and the consequent civil war, the appeal of the Southern States to Great Britain for aid, the arming of the slaves against their masters, and the outbreak of hostilities with the Indians. If there is any accuracy in the dates as stated, Joseph Smith must have been a man of rare political sagacity and foresight.

At the present day most of our religious creeds and systems resemble the great ecclesiastical edifices of the middle ages; relics of days when faith was stronger and zeal was warmer. These magnificent relics may indeed be renovated by modern hands, and upon a humble scale they can be reproduced, but the power of originating such buildings has passed away, and ecclesiastical architecture is no longer a living art. So is it with the chief accepted systems of religion; they have come down to us in their existing form from periods with which we have nothing else in common; they are not in harmony

with the tone of modern life and thought, and could not have been established in modern times. Nevertheless, they stand firmly on their ancient foundations, and will long continue to stand, more or less altered and repaired in accordance with modern exigencies.

But the Mormon church is an exception; it has been founded in these latter days, and may be said to have introduced a new order of ecclesiastical architecture, although ancient materials have been largely employed. Hence the doctrines and history of this church appear to deserve careful study, for it presents to us a living example of what its mightier predecessors must have been in their early career. The extinct dinornis may be studied in the existing apteryx, and thus (borrowing a fresh metaphor) among the fossils of the past we seem to find one recent specimen, still full of organic life, illustrating the laws of growth, the habits, and the constitution of those species whose dry bones alone remain to us now. The living apteryx seems to be doomed ere long to become like its fossil congeners; if so, the time for study and observation is short.

Even those who have least sympathy with the peculiar doctrines of the Mormons may be willing to enter a protest in their favor, when the issue really lies between religious liberty and persecution. They are the only Christian sect that has suffered in our own days severe persecution at the hands of professing Christians, and their cause on that account demands especial sympathy from all who advocate absolute religious toleration.—*Fortnightly Review.*

MORE CONCERNING MECHANICAL TOOLS.[1]

By Rev. ARTHUR RIGG, M. A.

CUTTING edges are sometimes doubled, and thus the chisel passes into another group of tools—shears. The most common of these is the ordinary household scissors opened and closed by hand; when required for heavier work, then one handle is fixed in a vise, and both hands can be employed upon the other lengthened arm (*see* Figs. 1 and 2). At other times this double chisel opens with a spring, and then the workman only employs himself in closing such upon their work (Fig. 3). Compound lever power is sometimes introduced, and, as an example of this, here is a pair of very light shears called the "little giant" (Fig. 4), the mechanical contrivances in which are so adjusted that we can, smoothly and without jar, cut an iron rod one inch wide by one-quarter inch thick. The lightness of the tool and the ease in cutting are very noticeable. It is an American con-

[1] From a lecture delivered before the London Society of Arts.

trivance, and the bar of iron is cut with the same ease as though it were of lead. This results to some extent from both jaws approaching each other. The arrangement of levers, cams, and stays, is worthy of examination after the lecture.

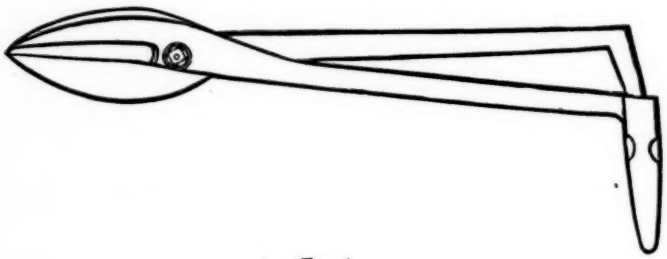


FIG. 1.

The use of the chisel, however skillfully handled, is not satisfactory over a surface wider than itself, although widened and made two-handed, as Fig. 5, and although the gouge has succeeded, or rather been planned to precede it, there is still a tendency almost unconquerable for the tool to follow the leadings of the fibres rather than cut through them at a very slight obliquity.

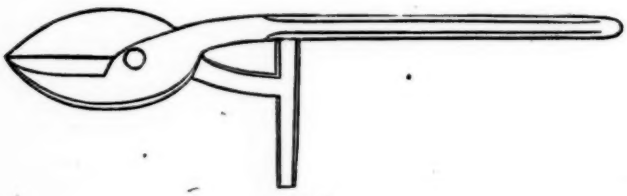


FIG. 2.

The only guidance either the axe, the adze, the pick, the gouge, or the chisel receives, is from the skill of the workman. Hence these tools produce such different work in different hands. However much it may be desirable to encourage skill in the workman, it is quite as desirable to furnish him with implements which shall make the least

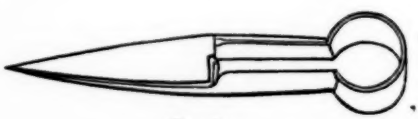


FIG. 3.

demand upon the exercise of this skill—which shall, in fact, so assist the skill in one or more directions as to permit all its care in some other direction. The assistance which the chisel needs is such as shall not only prevent it running deeper into the timber than is de-

sired, but shall enable it to be used with equal facility upon a broad as upon a narrow surface.

Given a rough piece of timber, nine inches wide and five feet long, to be smoothed by tools guided only by the handicraft skill of the workman, setting aside the adze as dangerous and unsuitable, the

Fig. 4.

probability is, that the tools selected would be gouges and chisels of various breadths and curvatures. The order of use would probably be, first, the narrow and deeply-curved gouges, ⌒, these to be followed by the shallower and broader, $\overset{A}{\frown}\overset{B}{}$, these again to be followed by the chisels, using in the first place a chisel wider than A B.

Let us consider what these tools would respectively accomplish if the timber is rough, as from the axe or pit-saw. The small gouge would corrugate the surface, ⌣⌣⌣⌣; the second gouge would enlarge the corrugation to this, ⌣⌣⌣⌣; and the chisel might render

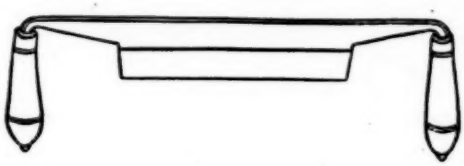


Fig. 5.

these more irregular. Such considerations as these, combined doubtless with others, led to the designing of what may be generally called the "guide principle," and this has been extended to various branches of artisan labor. At present we are only concerned with the application of this principle to gouges and chisels. This guide principle may consist of a guide as to the depth of cut, or as to the form of the

surface, or as to the direction of travel, or as to the correction of cross or longitudinal irregularities of surface.

The guide as to depth of cut is that which probably first presented itself as an important appendage to a chisel, and it has led to a form of tool of a very useful construction, although of limited range. The instrument is called a "spoke-shave." In this case the tool is that in Fig. 5 with the guide principle introduced, the depth of cut being determined by the nearness of the edge to a parallel wooden handle.

This tool, owing to the position of the application of the power, viz., the hands, and the tendency of resistance by the work to turn the whole tool in the hand, is not of general use; where, however, the curvature of surface varies, the parings to be removed are light, and the workman can have convenient access, the tool is one capable of doing good work, and, in some respects, possesses advantages over the plane, to which it probably formed an introduction.

The plane, in its most simple form, consists of a chisel inserted at an angle into a box, generally of wood, and with the cutting edge of the chisel projecting through the bottom of the box. If the actions of a workman be noted as he is smoothing wood with a chisel alone, it will be seen that he holds the bevel edge on the wood, and so elevates or lowers the handle as to secure a proper and efficient cut. Then he advances the tool in a line at right angles to its cross-section. If, now, instead of thus continuing to hold the tool, the chisel was so fixed in a movable piece of wood as to be at the same angle as the workman required, then, if the mouth were broad enough, and the instrument were propelled along the wood, a shaving would be removed very nearly the same as that obtained from the chisel alone.

In the arrangement thus sketched the workman would be relieved from the care needed to keep the tool at a constant angle with the surface of the timber. There is, however, a fixity of tool here, and consequently an optional or needful adjustment called for by any varying condition of the problem cannot be had. When operated upon by hand alone, if an obstacle to the progress of the tool is presented, as, for instance, a twist or curl in the fibre or grain of the plank—the presence of a knot—then the workman by hand can adjust the handle, and so vary the inclination of the cutting edge as the circumstances of the case require. Not so if the tool is securely fixed in a box as described.

While, therefore, one gain has been had, one loss has been encountered. Can the gain be made to more than counterbalance the loss? This can only be answered by observing the defects of the primitive plane, as hitherto described, and noting what hopeful elements it contains.

The front of the sole of the box will clearly prevent the penetration of the incased chisel into the wood, because it cannot now be

drawn to follow the fibre, should it lead inward. Suppose, however, that in the progress of the work such a place has been reached as would have so drawn the chisel inward. What will happen? Either the strength of the indrawing fibre will be so great that the workman will be unable to propel the tool, or, if not thus impeded, he must by extra effort separate the fibre and so release the tool. This separation, however, will not be by the process of cutting, but by that of tearing, and shavings so torn off will have left their marks in the roughnesses which attend the tearing asunder of fibrous woods. Thus the tool will defeat the very object for which it was designed.

Now, what is it which so forcibly draws, or tends to draw, the tool downward below the surface of the timber? The forces in operation are the hand of the workman and the tenacity of the fibre. If the tenacity is greater than the power, the workman must stop. That the tool cannot follow the direction of the fibre is clear, because the front part of the wooden sole forbids the penetration; but that it may be brought to a standstill, or must tear off the fibre, is also very clear. The mechanician has therefore to consider how to defeat these tendencies, which, as now sketched, result from a collision between the indrawing strength of the fibre and the power of the man to cross-cut the fibre by the tool, or else to tear it asunder and leave the surface rough.

Since the tool, as now contrived, cannot efficiently cross-cut the resisting fibre, and since that fibre has to be removed, the object must be either to prevent such an accumulation of fibres as will stop the progress of the tool, or to destroy the fibre piecemeal as it is operative for hinderance. Both plans have been adopted. A consideration of the former may prove introductory to the latter, which appears in almost all attempts to perfect this tool and its appended contrivance.

As the tool progresses, and the fibres become more and more impeding, it will be clear that a portion of this impediment results from a condensation of the fibre in the mouth of the wooden box. The more numerous the fibres admitted here, the greater will be the condensation. This state of affairs can be partially obviated by a narrowing of the mouth of the plane; such an act, of course, requires that the introduced chisel should enter less deeply into the timber being operated upon. Although thus abated, the cause is not removed, and even if so far abated as to prove no real impediment to the workman, yet the quantity of material removed on each occasion will be so small that the tool becomes one for finishing work only, and not for those various operations to which its present powers enable artisans to apply it.

To be the useful tool it is, the mouth must not be so narrowed, nor the inserted chisel so withdrawn, that the shaving is thus the thinnest

possible. This led to a contrivance now almost universal, that of breaking the fibre so soon as it is separated from the piece of timber. The designer seems to have considered that, as soon as a short length of shaving had been removed, it would be well to destroy the continuity of the fibre, and so prevent an accumulative resistance from this cause. Hence, instead of allowing the cut-off fibres to slide up the inserted chisel, he bent them forward, in fact, cracked them, and so broke the cumulative indrawing force of them. This he accomplished by the use of what is now called the back-iron, and henceforth the boxed-in chisel loses its identity, and must be regarded as part of an independent tool.

The tool thus built up is called a plane, and from its general utility, and capability of adaptation to various forms and conditions, it is well deserving of the high opinions entertained of its powers. Three forms of this tool are in general use in English workshops, called the "jack," the "trying," and the "smoothing" planes. These are on the bench of all workers in smooth, straight-surface wood. Although externally alike except in size, they are yet used for different purposes, and each has a specialty met with in its construction. These specialties may now be considered.

After the wood has passed from the sawyer into the hands of the carpenter, the surface undergoes those operations which render it true and smooth. These three planes do this work. The "jack," usually about fifteen inches long, and the "trying" plane, ranging from eighteen inches to twenty-four inches long, but, in exceptional cases, far exceeding these dimensions, are to external appearances alike; indeed, some regard the different handles as the only distinctions between them, and that these handles show which must be used for rough work and which for smooth (*see* Fig. 8 as an example of the handle of a "jack-plane," and Fig. 9 as an example of a "trying-plane handle"). This is an error. There are other differences, but the main and leading one is the different form given to the edge of the cutting-iron.

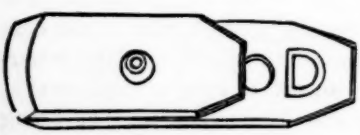


Fig. 6.

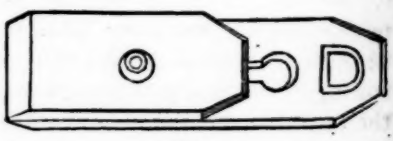


Fig. 7.

If the iron of the "jack" plane be looked at from the front end of the plane, the form of the edge will be curved, as in Fig. 6; but the iron of the "trying" plane is straight, as in Fig. 7. Upon the curvature of the edge depends the efficient action of the "jack."

Sufficient has been said of the tendency of the fibre to draw the tool downward; but it must not be forgotten that the same adhesion

of fibre to fibre takes place between the surface-fibres as among those below the surface. If tools excluded from this course of lectures had entered, we should have found that these connecting surface-fibres are separated by the addition of certain supplementary appendages to the tools. The depth to which the plane penetrates has led to the combination in one edge of such supplementary parts.

For the purpose of separating the surface connecting fibres, the jack-iron is convex. Note now its action. The convex sharp edge is pushed along an horizontal plank, penetrating to a depth determined by the projection of each vertical section below the sole of the plane. The ends of this convex edge are actually within the box of the plane; consequently (sideways) all the fibres are separated by cutting, and are therefore smooth and not torn. The effect of this upon the entire surface is to change the surface from the original section to a section irregularly corrugated. The surface after using the "jack" is ploughed, as it were, with a series of valleys and separating hillocks, the valleys being arcs from the convexity of the tool, and the separating hillocks being the intersections of these arcs. All traces of the tearing action of the saw have been removed, and from a roughened but level surface a change has been made to a smooth but in cross-section an undulating one.

The mechanician's next object is to remove these lines of separation between the valleys. For this, the trying-plane is required. The

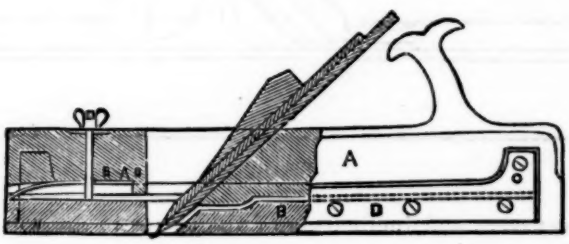


FIG. 8.

trying-plane is longer than the jack, because the sole of the plane which is level is, so far as its size goes, the counterpart of that which the surface of the wood is to be; further, the trying-plane should be broader than the jack, because its object is to remove the valleys, and not to interfere with the wood below the bottoms of the valleys. If its action passes below the bottoms of the furrows, then occasion arises for cutting the side-connection of the fibres, and, however a workman may sharpen the edge of his trying-plane for this purpose, he in one respect has destroyed one object of the plane, because, so soon as the iron penetrates below the surface, so soon does the effect of the jack-action begin to reappear, and the cutting edge should pass from the shape shown in Fig. 8 to the shape in Fig. 7. The result of

the trying-plane following the jack is to remove all the elevations of wood above the valleys the jack left; and, secondly, to compensate by its great length for any want of lineal truth consequent upon the depth of bite of the jack. Again, the mouth of the trying-plane is much narrower than that of the jack; hence the shavings removed are finer; therefore the slope of the iron, or its inclination to the wood, may be less than is the iron of the "jack"—hence the line of cut is more nearly accordant with that of the fibre, and by so much the surface is left more smooth from the trying-plane than from the jack, as there is more cutting and less tearing action than in the jack. The reasoning hitherto pursued in reference to the purpose of this sequence of a jack and trying plane might and does legitimately produce the conclusion that, after the trying-plane has done its duty, the work is as perfectly finished as it can be. Custom, and perhaps other considerations, have established that after the long trying-plane must follow the short and almost single-handed smoothing-plane. So far as the form of the iron of the smoothing-plane is concerned, there is no difference between it and the one used in the trying-plane; each (as across the plane) is straight, the corners being very slightly curved, but only so much as to insure that they do not project below the line of the cutting edge.

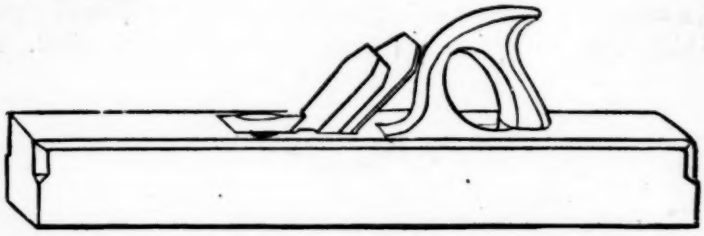


Fig. 9.

The facet edge and inclination of the cutter to the work, and the position of the back-iron, are now under consideration.

It would seem that, while the trying-plane leveled down all the elevations left by the jack, and brought the surface of the wood as a counterpart of that of the plane, there might be, in the fibre or grain of the wood, twists, curls, and other irregularities, which, while leveled, were yet left rough in consequence of the direction in which the cutting edge came upon them. Indeed, this cutting edge in a long plane, which must advance in the direction of its length, must at times come across a large number of surfaces where the fibre is in opposite directions. The consequence is, that there will be various degrees of smoothness; for good work these must be brought to uniformity. This is effected by passing a short-soled plane over the respective parts of the surface in such directions as observation may suggest. Hence the smoothing-plane is of use chiefly to compensate for such

changes in the direction of the fibres of the wood as the longer length of the trying-plane could not conveniently deal with. Hitherto, we have regarded the plane as arranged with a "guide principle" which shall always repeat a straight, level surface. The guide may, however, be the counterpart of any required surface. The plane made of iron, now in my hand, has an elastic steel sole, which, by means of adjusting screws, enables a workman readily to convert a straight-faced sole into one either concave or convex. This is an American production (*see* Fig. 10).

Fig. 10.

There is also in this and other planes a mode of fixing the iron which deserves more general adoption than it receives, viz., by a cam-action. It will often be noticed that, where the holding-wedge binds on the box of the plane in our ordinary planes, the wood has split. This arises from a commendable but, in this case, too strict a care for a good fit; hence the wedge is made tight where it should be slack.

WHAT AMERICAN ZOÖLOGISTS HAVE DONE FOR EVOLUTION.[1]

By Professor EDWARD S. MORSE.

II.

IN the "Memoirs of the American Academy of Sciences" may be found a profound mathematical essay "On the Uses and Origin of the Arrangement of Leaves and Plants,"[2] by the lamented Chauncey Wright. After discussing the laws of phyllotaxy, and showing that the botanist is wrong in supposing this a law at the outset, Mr. Wright states "one of the utilities, so to speak, in the apparently

[1] An address delivered at the meeting of the American Association for the Advancement of Science. Read at Buffalo, New York, August, 1876, by Edward S. Morse, Vice-President of Biological Section.

[2] "Memoirs of the American Academy," vol. ix., p. 379.

undeviating arrangement of leaves, to be the distributing of leaves most rapidly and thoroughly around the stem, exposed more completely to light and air, and provided with greater freedom for symmetrical expansion, together with more compact arrangement of bud;" and he asks, "What has determined such an arrangement of vital forces?" Theory of types would say, their very nature, or an ultimate creative power. Theory of adaptation would say, the necessity of their lives, both outward and inward; or the conditions, both past and present, of their existence.

Whatever tends to show modification in the markings, color, size, food, or change in the variety of habits manifested by animals, furnishes just so many indications of the unstable character of what had before been considered stable, and gives an infinitely wider field for those unconscious selections whose operations are coincident with every change in the physical features of the earth. On the theory of derivation additional confirmation is given to the deductions of geologists based upon the stratigraphical and paleontological evidences of the rocks. The survival of a marine crustacean in the deeper waters of Lake Michigan, as discovered by Stimpson, coupled with similar occurrences in the lakes of Sweden, suggests the past connection of these waters with the ocean. In the same way the persistence of arctic forms on high mountain-tops indicates the existence in past times of wide-spread glacial fields. The interesting discoveries of Mr. Ernest Ingersoll, in the Rocky Mountains, of the occurrence of two species of marine mollusks and living crabs belonging to marine forms, and tiny air-breathing mollusks peculiar to the Gulf coast and West Indies, point as distinctly to the past connection of that region with the ocean as the records of marine life left in the rocks. And more than this, the survival of these few forms gives us a conception of the thousands of animals which have succumbed to the changed conditions. Connected with the evidences of recent elevation of this region are the discoveries of Marsh in finding that, when the gill-bearing salamander *Siredon* is brought down from the colder waters of the Rocky Mountains to the warmer waters below, a complete change takes place in a loss of the gills and the conversion of the animal into the air-breathing genus *Amblystoma*.

This exhibits on a wider scale the experiments often performed in keeping tadpoles in the dark and cold, and indefinitely retarding their development, thus forcing them, as it were, to retain their earlier condition. Among the many millions of individuals of Amblystoma, some must have presented the anomaly of a premature development of their ovaries before the larval stage had passed away (similar cases being observed among insects), and thus it has been possible for them to perpetuate their kind in this stage. The Axolotl, having the longest persisted in this mode of growth, has become, as it were, almost fixed in these retrograde characters, only a

few examples being known in which the creatures have lost their gills and assumed the mature characters of Amblystoma, but with Siredon a change takes place with a proper change of surroundings.

To American students we are indebted for most valuable contributions regarding the effect of cave influences on animals living within their boundaries. Looking at the cave fauna with its peculiar assemblage of animals, it would seem that here, at least, the question as to the effects of certain external influences, or the absence of others in modifying structure, might be found.

Many years ago the editors of *Silliman's Journal* addressed a letter to Prof. Agassiz respecting the blind fishes of the Mammoth Cave, and asked his opinion as to whether their peculiar structure was due to their cave life, or whether they had been specially created. Agassiz's [1] reply is consistent with his belief. He says, "If physical circumstances ever modified organized beings, it should be easily ascertained here." He then expresses his conviction that "they were created under the circumstances in which they now live, within the limits over which they range, and with the structural peculiarities which characterize them at the present day," adding frankly, however, that these opinions are mere inferences.

With the contributions on cave insects by the eminent zoölogist Schiödte, and our own naturalists as well, we have now overwhelming proof that the blind fishes and numerous other cave animals are marked with peculiarities impressed upon them by the unusual environments to which they have been subjected.

In a work on the animals of the Mammoth Cave, by Dr. A. S. Packard and Prof. Putnam, the first-named writer quotes the results of Schiödte, wherein he shows the existence of twilight animals in which but slight modification occurs, while in darker places the changes become more profound.

Dr. Packard [2] sums up the results of his work as follows: "We then see that these cave animals are modified in various ways, some being blind, others very hairy, others with long appendages; all are not modified in the same way in homologous organs, another argument in proof of their descent from ancestors whose habits varied as their out-of-door allies do at present."

Prof. E. D. Cope,[3] in an article on the fauna of Wyandotte Cave, in commenting on the loss of eyes in cave animals from absence of light, and consequent disuse, says that, to prove it, "we need only to establish two or three propositions: 1. That there are eyed genera corresponding closely in other general characters with the blind ones. 2. The condition of the visual organs is in some cave type variable. 3. If the abortion of the visual organs can be shown to take place coincidently with general growth to maturity, an important

[1] *American Journal of Science*, second series, vol. xi., p. 128.

[2] "Life in the Mammoth Cave," p. 27. [3] *American Naturalist*, vol. vi., p. 415.

point is gained in explanation of the *modus operandi* of the process." He then proceeds to point out a number of related genera in which the external ones present eyes, while the cave forms are blind. As to variability, he cites the blind siluroid fish from Conestoga, Pennsylvania, showing that, while all of several specimens were blind, the degree of atrophy was marked not only in different fishes, but even on different sides of the same fish. In some the corium was perforate, in others it was imperforate. In some the ball of the eye was oval, in others collapsed.

We have in the meagre fauna of the caves convincing proof of the gradual undoing of parts—so to speak—on the withdrawal of influences favorable to them; even so exquisite a structure as the eye as a result of selection almost inconceivable, yet not only becoming rudimentary, but almost disappearing, by the withdrawal of those influences which were in part conducive to its building up. So distinct are these undoing stages that, were we sure of the stable variability of all of them, we could with certainty indicate the relative age of each cave inhabitant.

Prof. Alpheus Hyatt and Prof. E. D. Cope almost simultaneously established a number of propositions relating to certain large groups of animals which had never been recognized before. The theory of acceleration and retardation in which certain groups acquire rapidly new characters, while corresponding groups acquire the same characters more slowly, forms a portion of the theory of these naturalists. Prof. Hyatt has shown among Ammonites a parallel between the life-stages of the individual and similar stages in the group based upon an examination of suites of specimens as studied by him in Europe and America. It is utterly impossible to do the slightest justice to the thoroughly original views of these gentlemen without the aid of explanatory diagrams. While reluctantly abandoning the attempt, I must at the same time express the regret that neither of these investigators has seen fit to present to the public an illustrated and simple outline of the main features of their theories and the facts: Prof. Cope basing in part his propositions on groups of animals, many of which comprise fossil forms brought to light in the West, of which but few restorations have yet been made; and Prof. Hyatt basing his work on fossil Ammonites from the Jurassic and adjacent beds of Europe, of which but one complete collection is to be found in this country.

Surely, with this unfamiliar material, an excuse may be offered in not attempting a popular presentation of propositions and laws, some doctrinal and others theoretical, which must yet be looked upon as profound and permanent additions to the philosophy of evolution. A reference may be made to Prof. Cope's essays, entitled "Origin of Genera," "On the Method of Creation of Organic Types," "Consciousness in Evolution," "On the Theory of Evolution," and numer-

ous other memoirs from which may be gathered the author's views on the subject. The essays of Prof. Hyatt, "On the Parallelism between the Different Stages of Life in the Individual and those in the Entire Group of the Molluscan Order Tetrabranchiata," "Reversions among Ammonites," "Evolution of the Arietidæ," "Genetic Relations of the Angulatidæ," "Abstract of a Memoir on the Biological Relations of the Jurassic Ammonites," are altogether too technical to condense into an address of this nature. It need hardly be mentioned that in these memoirs invaluable contributions are made to the doctrines of natural selection. And now we come to the most difficult part of our work: to compass within the limits of a few pages the magnificent discoveries of Leidy, Marsh, and Cope, in the rich fossiliferous beds of the West. The wonders are so unique and varied; they have been poured upon us with such prodigality of material and illustration, that one is baffled in an attempt to compass their characters, or to picture them as realities. When Darwin offered the imperfection of the geological record as possibly accounting for the absence of intermediate forms which might have existed, he was at once met by a series of protests so strenuous, and at the same time so specious, that they had their full weight in staying the force of that prophetic chapter. Darwin, in this chapter, distinctly stated that not only were there forms which had never yet been seen, owing to the imperfection of the geological record, but that time might possibly bring them to light, and, when discovered, we should have revealed to us intermediate characters which would connect widely-separated groups as they are recognized to-day.

Behold the prophet! Animals have been discovered, not only showing the characters of two widely-separated groups, but in some cases of three groups as they now appear. How distinct the hoofed quadrupeds, the carnivora, and the rodents, appear to-day! Yet here are discovered ancestors of these widely-separate groups, in which are contained in one individual the characters of all three! Of the ungulates with the perissodactyle foot, there have been discovered a large number of tapiroid forms allied to Paleotherium; others which, like Anchitherium, wonderfully fill the gap between the horse and forms lower down; a large suite of rhinocerotic creatures of strange character and enormous size; a great number of species of three-toed horse, some no larger than foxes, and with these a perplexing maze of deer, antelopes, sheep, camels, hippopotami, and pig-like animals, ruminant-like beasts, some of them not larger than an ordinary squirrel: a curious group, comprising a large number of species with characters intermediate between the pigs and ruminants. Prof. Flower, the great English osteologist, confesses that these forms completely break down the line of demarkation between them, and adds that "a gradual modification can be traced in the characters of the animals of this group, corresponding with their chronological

position, from the earlier more generalized to the latest comparatively specialized forms, thus affording one of the most complete pieces of evidence that are known in favor of a progressive alteration of form, not only of specific, but even of generic importance through advancing ages." The probable home of the Camelidæ has been revealed in the discovery of llama-like creatures, gigantic mammals, in some cases exceeding the elephant in size, but with a diversity of characters hitherto unseen either in recent or fossil forms, combining as they did the characters of perissodactyle and proboscidian.

A numberless variety of Carnivora, many of them embracing the most generalized groups, have been brought to light, such as creatures between the wolf and the opossum, generalized dogs, and sabre-toothed cats.

A great many species belonging to the Rodentia, Insectivora, and Chiroptera, have been identified; still more wonderful is a group of creatures so unlike any beast heretofore known that Prof. Marsh has made a new order to include them under the name of *Tillodontia*. They combine the characters of several distinct groups, namely, the carnivores, ungulates, and rodents, and some of them in size equaling the tapir. Of great interest also is the discovery of fifteen new genera, belonging to low forms of primates. All of these creatures, embracing hundreds of species, are generalized in a high degree. New orders have been erected to embrace some of them. One has only to understand the specialization of modern animals to appreciate the generalized character of these early forms.

Prof. Marsh has shown that all the ungulates in the Eocene and Miocene had upper and lower incisors; and, again, that all the Eocene and Miocene mammals, including the Carnivora, had two of the wrist-bones, the scaphoid and lunar, as distinct bones.

The class of birds so long represented as a closed type can no longer occupy that isolated position. The proper interpretation of archæopteryx has, in the discoveries of Marsh, new interest. He has discovered a number of species of birds, for which a new sub-class is made. This sub-class will embrace two sub-orders, one in which the creatures had teeth contained in grooves in the jaws; the other had true teeth in the sockets. The first were swimming-birds of gigantic size, with rudimentary wings; the second embraced small birds, with powerful wings and bi-concave vertebræ.

Prof. Cope has also brought to light a remarkable gigantic bird from the Eocene of New Mexico; its size indicates a species with feet twice as large as those of the ostrich. He shows it to be distinct from any of the genera of *Struthionidæ* or *Dionornithidæ*. Besides all these wonders, a host of new forms of reptiles and fishes have been discovered by these indefatigable explorers—huge pterosauria discovered by Marsh with a spread of wing of twenty-four feet; and of more special interest is the fact that no trace of teeth can be found in the jaws.

It is impossible for me to more than allude to these remarkable additions to our knowledge of these early forms, and until they have all been figured with natural outlines, and perplexing questions as to priority in discovery rectified, it will be difficult in some cases to accredit individual work. But in the light of these profound revelations, how blind seem the attempts to establish a classification on the forms heretofore familiar to us, and to rear these into circumscribed groups between which it was asserted no forms of intermediate kinds were to be expected! With the twenty-five or thirty species of fossil horses at our command, some with four toes, others with three, in various stages of reduction, it is interesting to bring back to mind the earnest Geoffroy St.-Hilaire painfully endeavoring to trace the genealogy of the horse, with a few widely-separated forms of extinct mammals as his only guide in the work.

The special investigations of Marsh and Leidy reveal an almost unbroken line from our present horse with its simple toe, and two rudimentary metatarsals in the shape of the splint-bones, to a creature in which metatarsals support rudimentary toes, and still other forms in which these rudimentary toes are working-toes, and below that again another form in which a fourth toe is seen as a rudiment, till forms are reached in which all the toes rest on the ground. It is still more striking to study attentively those earlier generalized horses with four toes, and follow the successive reduction in the number of toes as the later formations are reached, till in the latest deposits and at present we have the modern specialized horse with but a single toe, the lost toes represented by two slender bones hidden beneath the flesh. And now comes crowning proof that our modern horse has been derived from some three-toed progenitor, for in certain instances horses have come into existence with splint-bones developed into sturdy bones sustaining at the extremities phalangeal bones, and outside accessory hoofs! Such freaks of Nature demand an explanation. They receive a rational one through the theories of Darwin. Without the law of reversion, we are left in blind bewilderment.

While all these facts in overwhelming array testify to the extreme mutability of forms, induced oftentimes by apparently the most trivial of causes, and set at rest the question as to the fixedness of species, they show at the same time the richness of that store from which by natural selection forms may be selected.

Realizing the uniformity of Nature's laws, the human mind bravely asks, "Do these wonderful interpretations throw any light upon the origin of man?"

Rigidly adhering to the inductive method, science is prepared to show that man did not appear suddenly and free from those animal proclivities and passions which make him a sinful creature, but that he has risen from a lowly origin, and his passions and desires, but feebly repressed, may be as surely traced to ancestral traits, as the

aberrant muscles in his structure may be recognized in some degraded progenitor. And in proof of this there is established a series of facts of precisely the same nature as is seen in those discoveries which link the horse in an almost unbroken line to earlier and more generalized animals.

It is instructive to read the discussions in relation to man's position in Nature as represented by Agassiz, Morton, and others.

The position that these eminent men were justified in taking shocked the Church, and received from her the same vigorous denunciations that Darwin was forced to bear at a later day.

The systematist, in formulating the separate species and genera of the apes and monkeys, was early led to see that man also in various parts of the world presented differences quite as striking, and if it were assumed, as indeed it was, that the peculiarities among men were only varietal, then it could be claimed with equal emphasis that the differences among apes were only varietal. Agassiz, in his keen grasp of things, readily saw this, and, since the races of men revealed differences just as specific in their characters as the animals immediately below them, he was forced to admit the plurality of origin of the human race. He says:

"Unless we recognize the differences among men, and we recognize the identity of these differences with the differences which exist among animals, we are not true to our subject, and, whatever be the origin of these differences, they are of some account; and if it ever is proved that all men have a common origin, then it will be at the same time proved that all monkeys have a common origin, and it will by the same evidence be proved that man and monkeys cannot have a different origin."

He confesses that he "saw the time coming when the position of the origin of man would be mixed up with the question of the origin of animals, and a community of origin might be affirmed for them all." With these convictions it is not surprising that he should have been led to express the opinions regarding the diversity of the human race that we find recorded.

Agassiz, in the meetings of the American Academy, repeatedly and in various ways illustrated the diversity of the human race. In one place he alludes to the difficulty in defining the species of man, and says the same difficulties occur in defining the species of anthropoid apes. We quote from the records:

"The languages of different races of men were neither more different nor more similar than the sounds characteristic of animals of the same genus; and their analogy can no more be fully accounted for on any hypothesis of transmission or tradition than in the case of birds of the same genus uttering similar notes in Europe and America."—("Proceedings of the American Academy," vol. iii., p. 6.)

Again, in a later volume, he expresses a general disbelief in the supposed derivation of later languages from earlier ones. He re-

garded each language and each race as substantially primordial, and ascribed their resemblances to a similarity in the mental organization of the races.

This extract illustrates the extremity to which one is logically driven if he accepts the hypothesis of special creation, and these words are quoted, not with the belief that at the present time they would have been uttered, but as illustrating the necessary admissions with the theory of plurality of origin. In precisely the same manner that Whitney, Müller, and other eminent philologists, have shown the outgrowth of present existing languages from primitive forms of language, so science is prepared to show the outgrowth of present men from primitive forms of animals. Agassiz was bitterly assailed by the Church for the bold attitude he assumed regarding the plurality of origin of the human race, though now that science will show that after all man has originated from a common centre, it seems no better satisfied. The facts bearing on man's lowly origin have been fully contributed by American students, and, as all intelligent men understand the bearing of these facts on the question, it is only necessary to allude to them here. If man has really been derived from an ancestor in common with the ape, we must expect to show—1. That in his earlier stages he recalls certain persistent characters in the apes; 2. That the more ancient man will reveal more ape-like features than the present existing man; and, 3. That certain characteristics pertaining to early men still persist in the inferior races of men.

Prof. Wyman[1] points out certain resemblances between the limbs of the human embryo and the permanent condition of the limbs of lower animals. In some human embryos about an inch in length he found that the great-toe was shorter than the others, and, instead of being parallel to them, projected at an angle from the side of the foot, thus corresponding with the permanent condition of this part in the Quadrumana.

In some observations made on the skeleton of a Hottentot, Prof. Wyman[2] calls attention to the complete ossification of the nasal bones, no trace of a suture remaining. This was more noticeable as the individual was young, and the other bones were immature, and had an interest "in connection with the fact that the nasal bones are coössified at an early period in the monkeys and before the completion of the first dentition in gorillas and chimpanzees." Careful measurements of the pelvis also revealed quadrumanous features, though "the resemblance is trifling in comparison with the differences."

In a study of the crania, Wyman[3] found differences in the relative position of the *foramen magnum*. In the North American Indian this opening was farther back than in the negro, while some crania from Kauai presented this opening still farther back than in the

[1] "Proceedings of the Boston Society of Natural History," vol. x., p. 185.
[2] Ibid., vol. ix., p. 352.
[3] Ibid., vol. xi., p. 447.

Indian; and more than half the lot from Kauai had the peculiarity in the nostrils first pointed out in the negro by Dr. John Neil, of Philadelphia, namely, the deficiency of the sharp ridge which forms the lower border of the opening. In its place is a rounded border, or an inclined plane.

This feature occurs very frequently in different races, but more rarely in Europeans. It is, however, never absent in the apes. Prof. Wyman, in studying the characters of certain ancient crania from a burial-place near Shell Mound, Florida, observed the *foramen magnum* quite far back, and remarks on the massive character of the bones composing the skull, the parietal being nearly twice the thickness of ordinary parietals, while the general roughness of the surfaces for muscular attachments on the hinder part of the head is very striking.[1]

In certain measurements of synostotic crania, Prof. Wyman found that the length of the parietals was twenty-four millimetres above the average, the parietals being lengthened from before backward, the frontal and occipital being but slightly augmented. Now, in the much-discussed Neanderthal skull, wherein it is urged by Dr. Davis that it is a synostotic skull, though denied by Huxley, Wyman shows that the parietals measure nine millimetres *below* the average, which is certainly against the view that the Neanderthal skull is synostotic.[2]

In an essay entitled "Observations on Crania and Other Parts of the Skeleton," Prof. Wyman shows that the relative capacity of the skull "is to be considered merely as an anatomical and not as a physiological characteristic,"[3] a most important distinction certainly in considering the large capacity of certain ancient skulls, since we must know the quality as well as the quantity in order to assume the intellectual position of the races. In this essay are also quoted the results of a large series of measurements made by Dr. B. A. Gould, in which it is shown that the arms of the blacks are relatively longer as compared with the whites, in this respect approaching the higher animals, a confirmation of the observations made by Broca, Pruner Bey, Lawrence, and others.

The perforation of the humerus, which occurs in the apes quite generally, was found to occur rarely in the white race. Of fifty humeri, Wyman found but two perforated, while of Indian humeri he found thirty-one per cent. perforated. In some of the remains of ancient men there has been found a remarkable lateral flattening of the tibia, unlike anything found at present, but always characteristic of the earliest races. These tibiæ have received the name of platycnemic tibiæ.

[1] "Fourth Annual Report of the Peabody Archæological Museum. Cambridge."

[2] "Proceedings of the Boston Society of Natural History," vol. xi., p. 455.

[3] "Fourth Annual Report of the Peabody Archæological Museum."

Wyman[1] quotes Broca as saying that the measurements of these tibiæ resemble the ape, and, what is more striking, in a small number of instances "the bone is bent and is strongly convex forward, and its angles so rounded as to present the nearly oval section seen in the apes." The occurrence of these platycnemic tibiæ has been noticed by several investigators. They have been obtained from the mounds of Kentucky by Mr. Carr, Mr. Lyon, and Prof. Putnam. Prof. Wyman found them in Florida mounds. To Mr. Henry Gillman, of Detroit, science is indebted for the discovery of the flattest tibiæ ever recorded, exceeding even those discovered in Europe. Mr. Gillman has opened a number of mounds along the Detroit and Rouge Rivers in Michigan, and assiduously studied the characters of these remains, which indicate a very ancient race of men. Many of these tibiæ he has sent to the Peabody Archæological Museum at Cambridge. Associated with these remarkable tibiæ he found large numbers of perforated humeri.

At the Detroit meeting of the Association, Prof. W. S. Barnard showed that the muscles which move the fingers and toes have been developed from one common muscle, and, in studying the various degrees of specialization of the muscles which move the hand and foot in the gorilla and lower apes, he finds that in the foot "man remains a creature of the past not modified by that which makes him a man, the brain. The hand has been modified and perfected by its services to the brain." Prof. Barnard also contributed another essay, entitled "Comparative Myology of Man and the Apes." From very careful studies he is led to believe that the relative position of the origin of the muscles is more constant than that of their insertions. In this examination he brings to light a muscle which Traill dissected in the higher apes, and which he called the *scansorius*, and this was supposed to have no representative in man.

Traill was followed by Wyman, Owen, Wilder, and Bischoff, who, in a controversy with Huxley, argued from this muscle against the simian origin of man. Mr. Barnard now shows that Traill was mistaken, and that other naturalists were misled by the weight of his authority. What Traill interpreted as the *gluteus minimus* is the *pyriformis*, and what he figured as a new muscle separating the apes from man, the *scansorius*, is the *homologue* of our *gluteus minimus*.

From gradually accumulating data, in regard to microcephalic skulls, it would seem as if Carl Vogt were right in judging them to be cases of reversion. Prof. Wyman says, in regard to a microcephalic skull from Mauritius, that, "taking together the high temporal ridges, the union of the temporals with the frontals, the projection of the jaws, the narrow and retreating forehead, the small capacity, and the form and proportions of the nasal openings, the general resemblance to that of an ape is most striking, and seems to justify Vogt's expres-

[1] "Fourth Annual Report of the Peabody Archæological Museum."

sion of a man-ape, it being understood that the skull we are describing is not a natural, but an anomalous formation."[1]

It would be difficult to imagine, indeed, that mere reduction in the size of the brain, through arrest of development, should produce a series of characters so closely resembling the apes as is found to be the case in so many widely-separated examples. Thus, in the Mauritius microcephalic skull the capacity is only twenty-five cubic inches. The jaws are extremely prognathous, the zygomatic arches stand out wide and free, and the temporal ridges approach within one and a quarter inch. If such examples should prove to be veritable cases of reversion, then we have a parallel in the startling appearance of the long-lost rudimentary toes of the horse, traces of which are only seen in the hidden splint-bones. In the "Seventh Annual Report of the Archæological Museum," Prof. Wyman describes a microcephalic skull from the ancient *huacals* of Peru. Its capacity is only thirty-three cubic inches; "the frontal bone is much slanted backward, has a decided ridge corresponding to the frontal suture, and is slightly concave on each side of it."

Wyman states that the bones of the head are well formed, though, from the diminutive size of the brain, idiocy must have existed.

Associated with the remarkable collection of platycnemic tibiæ and perforated humeri discovered by Mr. Henry Gillman, we should have expected some anomalous forms of crania, and in this expectation we are not disappointed.

In company with two skulls which appear to be normal, Mr. Gillman discovered one of most remarkable proportions. Wyman considers it a case of extreme individual variation, and not the result of artificial deformity. The skull in question has only a capacity of fifty-six cubic inches. The average capacity of Indian crania, according to Morton's measurements, being eighty-four cubic inches, and the minimum capacity being sixty-nine cubic inches, the skull of Gillman is therefore thirteen cubic inches less than the smallest Indian skull heretofore described. But more extraordinary still is the approximation of the temporal ridges. While in ordinary crania the separation of these ridges is usually from three to four inches, and never less than two inches, in this unique skull from the Detroit River mound the ridges in question approach within three-quarters of an inch, in this respect, as Wyman says, presenting the same condition as that of the chimpanzee. A rounded median crest can be distinctly seen and felt between these ridges, and the skull is markedly depressed on each side for the passage of the powerful mastoid muscles.

Is this, too, a case of partial reversion? Such extraordinary forms as the Neanderthal and Engis skulls, and the one above cited, with the La Naulette and other lower jaws, could not have been uncommon in those early days, since the chances against finding them

[1] "Seventh Annual Report of the Peabody Archæological Museum."

would be simply enormous, unless, indeed, they were of common occurrence. Looking at these remains as at the remains of other mammals, we must admit either that these low characters represent retention of ancestral peculiarities, or that they are cases of reversion. In considering the Neanderthal skull, with its retreating frontal, its enormous frontal crest, and other anthropoid characters, Huxley is led to say that at most there is "demonstrated the existence of a man whose skull may be said to revert somewhat toward the pithecoid type."

To a mind unbiased by preconceived opinions, and frankly willing to interpret the facts as they stand revealed by the study of these ancient remains the world over, the evidence of man's lowly origin seems, indeed, overwhelming.

Looking at the whole question impartially, we find that among recent men there are high types as well as low types, with a variation so great as to have induced Agassiz, Morton, and others, to consider them specific. And while, as Wyman asserts, no one race possesses all the low characters, yet with the relatively long arms, the tendency of the pelvis to depart from the normal proportion, and numerous other facts of like significance, there are yet retained among some of them more resemblances to the higher apes than can be found among others.

Prof. Cope, not content with tracing man back to some ape-like progenitor, has, in a suggestive way, considered man's relations to the Tertiary mammalia. In a communication to the Association at Detroit, on this subject, he prefaced his paper by saying that in the doctrine of evolution two propositions must be established: 1. That a relation of orderly succession of structure exists, which corresponds with a succession in time; 2. That the terms (species, genera, etc.) of this succession actually display transitions or connections by intermediate forms, whether observed to arise in descent, or to be of such varietal character as to admit of no other explanation of their origin." He shows that the primary forms of mammalia are strongly indicated in the structure of the feet, and also in the character of the teeth. In recent land-mammals there are several types of foot to be recognized, the many-toed plantigrade, the carnivorous, the ox, and the horse types. Among the earlier types of the Eocene, he finds the most generalized type in the Coryphodon of Owen (Bathmodon of Cope). This creature was plantigrade, with a short calcaneum, and an imperfect hinge for the foot. From this generalized form he traces a line of succession of intermediate forms to the horse on the one hand, and the ox on the other.

The Coryphodon was one of the earliest known mammals, while the horse and the ox preceded man by a single geological period. Without entering into a technical description of the successive forms presented by Prof. Cope, we may quote his words wherein he shows

that "the mammals of the Lower Eocene exhibit a greater percentage of types that walk on the soles of their feet, while the successive periods exhibit an increasing number of those that walk on the toes; while the hoofed animals and Carnivora of recent times nearly all have the heel high in the air, the principal exceptions being the elephant and bear families." After presenting the gradual osteological changes of the foot, from the earlier types to the later ones, through several lines of descent, considering also the teeth as well, he says: "The relation of man to this history is highly interesting. Thus, in all generalized points, his limbs are those of the primitive type, so common in the Eocene. He is plantigrade, has five toes, separated tarsals and carpals, short heel, rather flat astragalus, and neither hoofs nor claws, but something between the two; the bones of the forearm and leg are not so unequal as in the higher types, and remain entirely distinct from each other, and the ankle-joint is not so perfect as in many of them. In his teeth his character is thoroughly primitive....

"His structural superiority consists solely in the complexity and size of his brain. A very important lesson is derived from these and kindred facts. The monkeys were anticipated in the greater fields of the world's activity by more powerful rivals. The ancestors of the ungulates held the fields and the swamps, and the Carnivora, driven by hunger, learned the arts and cruelties of the chase. The weaker ancestors of the Quadrumana possessed neither speed nor weapons of offense and defense, and nothing but an arboreal life was left them, where they developed the prehensile powers of the feet. Their digestive system unspecialized, their food various, their life the price of ceaseless vigilance, no wonder that their inquisitiveness and wakefulness were stimulated and developed, which is the condition of progressive intelligence"—adding that "the race has not been to the swift, nor the battle to the strong." Prof. Cope shows in this case that "the survival of the fittest has been the survival of the most intelligent, and natural selection proves to be, in its highest animal phase, intelligent selection."

Prof. Fiske has in a clearer way shown that when variations in intelligence became more important than variations in physical structure, then they were seized upon, to the relative exclusion of the latter.

It is intelligent strength, other things being equal, that conquers the savage, and the gradual selection of the best and biggest brains is not seen alone in man.

In one of the most significant discoveries of Prof. Marsh, the mammalia are found to show an increase in the size of the brain coincident with their succession in the rocks.

One of the most extraordinary mammals from the Tertiary beds of the West is the Dinoceras, with its rhinoceros and elephant characters, its skull ornamented with prominent tubercles, its unique den-

tition, embracing large cutting tusks, and altogether forming a beast like the fabled monsters of old.

A study of its cranial cavity, made by Prof. Marsh, shows that its brain was proportionally smaller than that of any known mammal. Indeed, it was almost reptilian, and of such diminutive size that it could have been drawn through the neural canal of all the presacral vertebræ. Prof. Marsh has followed up this discovery with the most important results, and is now prepared to state the following conclusions:

1. That all the Tertiary mammals had small brains.
2. There is an increase in the size of the brain during this period.
3. This increase was mainly confined to the cerebral hemispheres or higher portion of the brain.
4. In some groups the convolutions of the brain have gradually become more complicated.
5. In some the cerebellum and olfactory lobes have even diminished in size.

He also finds some evidence that the same general law holds good for birds and reptiles from the Cretaceous to the present time.[1]

Thus we have in other groups as well as man convincing proof that, with successive survival of forms, there is a corresponding survival of larger brains.

Prof. Shaler[2] has offered some suggestive thoughts in showing the intense selective action which must have taken place in the shape and character of the pelvis in man, on his assumption of the erect position—the caudal vertebræ turning inward; the lower portion of the pelvis drawing together to hold the viscera, which had before rested on the elastic abdominal walls; the attending difficulties of parturition, and other troubles in those parts—all pointing to the change which has taken place.

In this connection Prof. Shaler remarks that the question of labor in woman must not be overlooked from this standpoint.

In a memoir on the shell-heaps of Florida, by Prof. Wyman, wherein he describes a number of low characters in man already alluded to, he gives the following conclusions: "The steady progress of discovery justifies the inference that man in the earlier periods of his existence, of which we have any knowledge, was at most a savage, enjoying the advantage of a few rude inventions. According to the theory of evolution, which has the merit of being based upon, and not inconsistent with, the observed analogies and processes of Nature, he must have gone through a period, when he was passing out of the animal into the human state, when he was not yet provided with tools of any sort, and when he lived the life of a brute."[3]

[1] *American Journal of Science*, vol. xii., July, 1876.

[2] "Proceedings of the Boston Society of Natural History," vol. xv., p. 188.

[3] "Memoirs of the Peabody Academy of Sciences," vol. i., part iv.

These words have no obscure significance, and when we regard the character of the one who wrote them, his cautious methods of research, and the long deliberation he was wont to give to all such questions, then they become doubly important.

Recognizing clearly the existence of these lower and earlier stages in man, it has been one of the most difficult problems to solve the first steps toward his society and family relations. Prof. John Fiske, in his "Outlines of Cosmic Philosophy," has given for the first time a rational explanation of the origin and persistence of family relations, and thence communal relations, and, finally, society.

Never before has there been presented so clear an idea of man's physical changes, and the effects of natural selection in seizing upon attendant or correlated nervous changes, as in the work of this author.

Prof. Fiske says: "Civilization originated when in the highest mammals variations in intelligence became so much more important than variations in physical structure that they began to be seized upon by natural selection, to the relative exclusion of the latter."[1]

Starting from the researches of Sir Henry Maine, Lubbock, and others, he finds social evolution must have originated after families temporarily organized among the higher mammals had become permanently organized. But how this step was effected has been an insoluble problem. Bagehot, in his remarkable work on "Physics and Politics," says: "It is almost beyond imagination how man, as we know man, could by any sort of process have gained this step in civilization." Darwin supposes that men were originally weak and inoffensive creatures, like the chimpanzee, and were compelled to band together to make up in combined strength what they lacked as individuals.

That man, for his age, is a weak animal physically, there can be no doubt. Fiske shows that "increase of intelligence in complexity and specialty involves a lengthening of the period during which the nervous connections involved in ordinary adjustments are becoming organized." From these conditions arose the phenomena of infancy, and he shows that with increase of intelligence infancy becomes longer. In the human race it is longer than in any other mammal, and much longer in civilized man than in the savage.

In the orang-outang the infant does not begin to walk till it is a month old, and in performing this act it holds to various objects for support, as in the human infant. Previous to that time it reposes on its back, and becomes absorbed in gazing at its hands and feet. Now, still lower down among the monkeys, at the age of one month the young are fully matured so far as walking and prehension are concerned. It is shown, furthermore, that where infancy is very short, parental feeling may be intense for a while, but soon dies out,

[1] "Cosmic Philosophy," vol. ii., p. 340.

and the offspring of one becomes of no greater interest than those of a stranger, "and in general the duration of the feelings which insure the protection of the offspring is determined by the duration of the infancy. . . .

"Hence if long infancies could have suddenly come into existence among a primitive race of ape-like men, the race would have quickly perished from inadequate persistence of parental affection." Prof. Fiske, in a most reasonable way, shows that "the prolonged helplessness of the offspring must keep the parents together for longer and longer periods in successive epochs; and when at last the association is so long kept up that the older children are growing mature while the younger ones still need protection, the family relations begin to become permanent. The parents have lived so long in company that to seek new companionships involves some disturbance of ingrained habits, and meanwhile the older sons are more likely to continue their original association with each other than to establish associations with strangers, since they have common objects to achieve, and common enmities bequeathed, inherited or acquired with neighboring families."

In his chapter on the moral genesis of man Fiske maintains that "the prolongation of human infancy accompanying the development of intelligence, and the correlative extension of parental feeling, are facts established by observation wherever observation is possible; and to maintain that the correlation of these phenomena was kept up during an epoch which is hidden from observation, and can only be known by inference, is to make a genuine induction, involving no other assumption than that the operations of Nature are uniform. To him who is still capable of believing that the human race was created by miracle in a single day, with all its attributes, physical and psychical, compounded and proportioned, just as they now are, the present inquiry is of course devoid of significance. But for the evolutionist there would seem to be no alternative but to accept, when once propounded, the present series of inferences."

Recalling now the various evidences educed by Wyman, Giman, and others, regarding the anomalous characters of the remains of primitive man, it seems impossible that a mind unbiased by preconceived opinion should be able to resist the conviction as to man's lowly origin.

If we take into account the rapidly-accumulating data of European naturalists concerning primitive man, with the mass of evidence received in these notes, we find an array of facts which irresistibly point to a common origin with animals directly below us, and these evidences are found in the massive skulls with coarse ridges for muscular attachments, the rounding of the base of the nostrils, the early ossification of the nasal bones, the small cranial capacity in certain forms, the prominence of the frontal crest, the posterior position of

the *foramen magnum*, the approximation of the temporal ridges, the lateral flattening of the tibia, the perforation of the humerus, the tendency of the pelvis to depart from its usual proportions, and, associated with all these, a rudeness of culture and the evidence of the manifestation of the coarsest instincts. He must be blind indeed who cannot recognize the bearing of such grave and suggestive modifications. But what application are we to make of such revelations if we vividly receive them as such? We are no longer to rest with the blind fatalism of the Turks, or listless resignation of the masses, but are to make a living use of them. We are to trace evil and corrupt passions to their source. The dreadful outrages which shock us from time to time in the public prints are not instigated by an evil spirit, but are outbursts of the same savage nature which found more frequent expression years ago, and which are still present with the lower races of to-day. When the study of heredity reveals the fact that even the nature of vagabondage is perpetuated; when the surprising revelations of Margaret, mother of criminals, from whose loins nearly a thousand criminals have thus far been traced, are considered, common-sense will ultimately recognize that the imprisonment of a criminal for ten or twenty years is not simply to punish him or relieve the public of his lawless acts, but to restrain him from perpetuating his kind. No sudden revulsion of feelings and amended ways is to purify the criminal taint, but he is to be quarantined in just the same way that a case of the plague might be, that his kind may not increase. With these plain facts thoroughly understood, men high in authority must find some other excuse for the exercise of their pardoning power, and other reasons be given for allowing so large a proportion of criminals to go free. With the monstrous blot of Mormonism and free-love in our country, the statute-books are to be again revised from the standpoint of science, with its rigid moral and physical laws, and not from the basis of established usage or long-continued recognition.

THE LAWS OF HEALTH.

By THOMAS BOND, F. R. C. S.

ON an average, one-half of the number of out-patients treated by a hospital-surgeon suffer from diseases due primarily to a want of knowledge of the laws of health and cleanliness. 1. The ignorance of hygienic laws, which affects so disastrously the health of the rich as well as the poor, exists chiefly in regard to dress, ablution, and ventilation. This statement may, at first, appear startling, but an enumeration of the diseases that can be constantly traced to the above causes will show upon how sound a basis the statement rests. The

following are examples: Varicose ulcers from dress; skin-diseases from want of cleanliness; chest-diseases and fevers from defective ventilation. The vast number of ulcerated legs treated in the out-patient department of hospitals, in workhouse infirmaries, and in private practice, arise from varicose veins. Now, a varicose ulcer is caused by a distended condition of the veins of the leg, which have to sustain the pressure of the blood caused by gravitation. In varicose veins, the valves which help to support the column of blood are to a great extent destroyed, through the veins having been distended by mechanical obstruction to the free return of the blood from the extremities, thereby distending the lower veins and separating the edges of the valves. Thus, the weight of an uninterrupted column has to be borne by the veins. This, of course, causes further distention, giving rise to congestion of the capillaries of the skin, and causing swelling, eczema, and ultimately ulceration. This is the varicose ulcer so common in the laboring-classes. It is always difficult to heal, and often impossible, except by prolonged rest in bed. Hence it is the dread of the surgeon, and the cause of misery to thousands. Varicose ulcers are seldom admitted into general hospitals, so that hundreds of poor families are driven to the workhouse, and such cases form a majority in the workhouse infirmary. The most frequent and flagrant cause of obstruction is the ordinary elastic garter. Children should never wear them at all, as the stockings can be perfectly well kept up by attachment of elastic straps to the waistband. If garters are worn, it is important to know how to apply them with the least risk of harm; at the bend of the knee the superficial veins of the leg unite, and go deeply into the under part of the thigh beneath the ham-string tendons. Thus a ligature below the knee obstructs all the superficial veins, but if the constriction is above, the ham-string tendons keep the pressure off the veins which return the blood from the legs; unfortunately, most people, in ignorance of the above facts, apply the garter below the knee. Again, in nine out of ten laboring-men, we find a piece of cord or a buckled strap tightly applied below the knee, for what reason I could never learn. Elastic bands are the most injurious. They follow the movements of the muscles, and never relax their pressure on the veins. Non-elastic bands during muscular exertion become considerably relaxed at intervals, and allow a freer circulation of the blood.

2. The habit of tight lacing again predisposes to varicose veins, in consequence of the abdominal viscera being pushed downward into the pelvis, causing undue pressure on the veins of the lower extremities when they enter the pelvis. Physicians also have reported numerous cases of heart and lung disease caused by this pernicious habit.

3. The use of dress is often misunderstood. Most persons evidently study and practise it with regard to appearance, or only to keep out wet and cold. The hygienic use of clothes, however, is not so much

to keep cold out as to keep heat in. The mistake is often made, of taking great care to put on extra wraps and coats when preparing for out-door exercise. This is not at all necessary in robust persons. Sufficient heat to prevent all risk of chill is generated in the body by exercise. The care should be taken to retain sufficient clothing after exercise, and when at rest, to prevent the heat passing out of the body. Indeed, persons very often catch chills from throwing off extra clothing after exercise, or from sitting about in garments, the material of which is not adapted to prevent the radiation of heat from the body. Linen and cotton under-clothing, when moistened by perspiration, parts with heat very rapidly, whereas flannel and silk, being non-conductors, prevent the rapid loss of heat.

4. The most recent offense against the laws of health is the habit of wearing false hair. The perspiration of the scalp is prevented, by the thick covering, from evaporating, thereby causing a sodden and weakened condition of the skin, which predisposes to baldness and other diseases of the scalp. Again, it produces headache and confusion of the intellectual faculties. We all know what a relief it is, during hard mental work, simply to raise one's hair by running the fingers through it. I should think literary ladies either do not wear false hair, or take it off when at work.

5. Ablution is another subject of paramount importance to health. Mr. Urquhart, the introducer of the Turkish bath into this country, is one of the benefactors of the age, and it is to be hoped some day there will be a bath in every town and village in England. Doctors are very much to be blamed for allowing themselves to be prejudiced against it. The usual opinion given by medical men to their patients is, that it is debilitating, and only to be borne by the robust. The reverse is really the case: it is stimulating and strengthening, it is a preventive as well as curative in disease. The effect of the Turkish bath on the skin is to cause an active condition of its functions of elimination, by removing the hardened epithelial scales, by removing the fat from the pores, and by causing the sweat-glands to maintain the activity of their functions, giving a general stimulus to the vital power of the skin. Again, it keeps the body in a state of perfect cleanliness, which is so essential to robust health; but these are not its only virtues—it promotes purity of mind and morals. The man who is accustomed to be physically clean shrinks instinctively from all contact with uncleanliness.

6. There are, however, certain precautions to be observed in the use of the baths. Persons who are apoplectic, or suffering from fatty degeneration of heart, should not venture to disturb the circulation by the excitement of baths. The first effect of Turkish baths is to stimulate the circulation, the second to cause active congestion of the skin, the third to produce profuse perspiration, the fourth to keep down the temperature of the body by rapid evaporation. On leaving the

Turkish bath the body should be douched with cold water; the capillaries are thus emptied of their blood by contraction, but immediately after the stimulation causes them to resume a state of activity, and produces vigorous circulation through the skin.

7. In taking a cold bath in the morning the same conditions should be present. The surface of the body should be warm and moist; therefore, the bath should be taken immediately on rising from the bed, and before the surface of the body has had time to cool or the capillaries to contract. The shock of the cold water should cause them suddenly to contract; then quick reaction will take place in the same way as after a Turkish bath. Unless this reaction occurs after the bath, there is great danger of getting a chill; at any rate, the full benefit of the bath is not obtained. Persons with weak circulation, who cannot take an ordinary morning bath, often derive great benefit from the Turkish bath. It opens the pores and improves the circulation of the skin, so that the shock of cold water can afterward be borne. The same persons can generally bear a cold bath if they get for a few minutes into a warm bath first, and then immediately plunge into cold water. By these means an active reaction is brought about. Warm baths should, in my opinion, never be taken on rising except under the above conditions, but warm baths at night are often desirable. They should be taken just before going to bed, when they have the effect of relaxing the muscular system and of promoting sleep by soothing the activity of the brain by the withdrawal of blood from it. I do not think warm baths at night are weakening, as the depression of vital energy which may occur is recovered during sleep. In river and sea bathing, persons should be careful not to remain in the water too long, nor should they exert themselves sufficiently to cause exhaustion, as the power of reaction is much impaired thereby; neither should persons get into cold water when cooling. The old-fashioned idea that persons should wait to cool before plunging into the water is a fallacy. There is no danger in plunging into the coldest water in a state of profuse perspiration, if the heart and arteries are in a healthy state. Of course, it would be unwise to do so immediately after a full meal, as the action of the heart might be impeded by the distended stomach.

8. Many persons complain of always getting up tired in the morning. This is very often due to defective ventilation of the bedroom, or from using an undue amount of bedclothes and bedding. Feather beds are too soft and yielding, and partially envelop the sleeper, thus producing profuse perspirations. The habit of lying too much under blankets is also very pernicious, by reason of the carbonic acid exhaled by the sleeper being respired. Again, it is a common error to suppose that, by simply opening a window a little at the top, a room can be ventilated. People forget that for proper ventilation there must be an inlet and outlet for the air. In bedrooms there is often

neither, and if there is a fireplace it is generally closed up. Again, it is a mistake to suppose that foul air goes to the top of a room. Certainly the heated air goes to the top, but the chief impurity, the carbonic acid, falls to the bottom. There is nothing so efficacious in removing the lower strata of air as the ordinary open fireplace, especially if there is a fire burning. The usual defect in ventilation is the want of a proper inlet for the air. If the window be open, the cold air, being heavier, pours down into the room, causing draughts; if the door be open or ajar, the same thing occurs. The perfection of ventilation may be obtained in any room with a fireplace by simply providing proper inlets for the air, and nothing answers so well for the purpose as the upright tubes invented by Mr. Tobin. By this means the heavier external atmosphere ascends vertically through the tubes like the jet of a fountain, displacing the warmer and lighter atmosphere of the room, which finds its exit up the chimney. The tubes should communicate with the outer air on a level with the floor, and should be carried vertically upward in the room for about four or five feet. A constant supply of fresh air is thus insured without the slightest liability to draught, as the current goes directly upward until it strikes the ceiling. It is then diffused downward, mixed with the heated air of the ceiling. The same principle can be carried out in any room with a sash-window, by cutting out two or three holes an inch wide and three inches long in the wood-work of the upper sash where it joins the lower one. The columns of air ascend directly upward, just inside the window, and mix with the heated air in the upper part of the room. If this system were universally carried out, we should hear less of rheumatism and chills caught by sitting in draughts.

9. Persons should cultivate the faculty of detecting sewer-gas in houses. Typhoid fever is often caused by the escape of this gas into the house through defect of the traps and drains. However bad the drains may be outside of the house, there is little to fear, provided the gas can escape externally. The following two very simple precautions would naturally diminish the cases of typhoid fever: First, every main drain should have a ventilating-pipe carried from it, directly outside of the house, to the top of the highest chimney; secondly, the soil-pipe inside the house should be carried up through the roof, and be open at the top.—*English Mechanic.*

CANINE SAGACITY.

A CORRESPONDENT hands us the following anecdotes illustrative of the remarkable reasoning powers of dogs:

The first case is one which occurred at a fashionable watering-place on the east coast of Ireland, some twenty years ago, and exhibits the remarkable sagacity displayed by a dog in carrying out the dictates

of the animal passion for revenge. The jetty which stretched along the small harbor was at that time used as a promenade by the *élite* among the sojourners on the coast, where, after the heat of the long summer days, they regaled themselves with the fresh evening breezes wafted in from the sea. Among the frequenters of this fashionable resort was a gentleman of some position, who was the owner of a fine Newfoundland dog, which inherited the time-honored possessions of that noble breed—very great power and facility in swimming; and, at the period of the evening when the jetty was most crowded with promenaders, his master delighted to put this animal through a series of aquatic performances for the entertainment of the assembled spectators. Amusement being at a premium on the coast, these nightly performances grew into something like an "institution," and the brave "Captain"—for such was his name—speedily became a universal favorite on the jetty. It happened, however, that among the new arrivals on the coast there came a certain major in her majesty's army, accompanied by two bull-dogs of unusual size and strength, and of great value; but, value in a bull-dog being inversely proportionate to its beauty, the appearance of the major and his dogs excited no very enthusiastic pleasure among the æsthetic strollers on the jetty. On the first night on which the major presented himself, nothing unusual occurred; and Captain dived and swam as before. But on the second evening the brave old favorite was walking quietly behind his master down the jetty, when, as they were passing by the major and his dogs, one of these ugly brutes flew at Captain, and caught him by the neck in such a way as to render his great size utterly useless for his defense. A violent struggle ensued, but the bull-dog came off the victor, for he stuck to his foe like a leech, and could only be forced to release his hold by the insertion of a bar of iron between his teeth. The indignation of the by-standers against the major was, of course, very great; and its fervor was not a little increased when they saw the poor Captain wending his way homeward, bleeding, and bearing all the marks of defeat. Some two or three evenings after this occurrence, when Captain again made his appearance on the jetty, he looked quite crestfallen, bore his tail between his legs, and stuck closely to the heels of his master. That evening passed away quietly, and the next, and the next, and so on for about a week—Captain still bearing the aspect of mourning. But one evening about eight or ten days after the above encounter, as the major was marching in his usual pompous manner along the jetty, accompanied by his dogs, something attracted his attention in the water, and, walking to the very edge of the jetty, he stood for a moment looking down into the sea. Scarcely had the two bull-dogs taken up their stand beside their master when Captain, seizing the opportunity for which he had so long looked, rushed at his former conqueror, and, catching him by the back of the neck, jumped off the jetty, with his foe in his mouth, down some twen-

ty feet or more into the sea. Once in the water, the power of his enemy was crippled, while Captain was altogether in his own element; and, easily overcoming all efforts at resistance, he succeeded in resolutely keeping the bull-dog's head under water. The excitement on the shore was, of course, intense. The major shouted, and called out: "My dog! my beautiful dog! Will no one save him?" But no one seemed at all inclined to interfere, or to risk his life for the ugly dog. At length the major called out: "I'll give fifty pounds to any one who will save my dog;" and soon afterward a boat which lay at some little distance pulled up to the rescue. Even then, however, it was only by striking Captain on the head with the oars that he could be forced to release his victim, which was taken into the boat quite senseless from exhaustion and suffocation, and was with difficulty brought to itself again. Captain, on the other hand, swam in triumph to the shore, amid the plaudits of the spectators, who shared, in sympathy at least, his well-earned honors of revenge.

More remarkable than the sagacity in carrying out the desire for revenge, displayed by the Newfoundland dog in the above case, is that which the following narrative illustrates: A gentleman of wealth and position in London had, some years ago, a country-house and farm about sixty miles from the metropolis. At this country residence he kept a number of dogs, and among them a very large mastiff and a Scotch terrier; and, at the close of one of his summer residences in the country, he resolved to bring this terrier with him to London for the winter season. There being no railway to that particular part of the country, the dog traveled with the servants in a post-carriage, and on his arrival at the town-house was brought out to the stable, where a large Newfoundland dog was kept as a watch-dog. This latter individual looked with anything but pleasure on the arrival of the little intruder from the country; and consequently the Scotch terrier had not been very long in his new home when this canine master of the stable attacked him, and, in the language of human beings, gave him a sound thrashing. The little animal could, of course, never hope by himself to chastise his host for this inhospitable welcome, but he determined that by some agency chastisement should come. Accordingly, he lay very quiet that night in a remote corner of the stable, but when morning had fully shone forth he was nowhere to be found. Search was made for him, as the phrase says, high and low, but without success; and the conclusion reluctantly arrived at was, that he had been stolen. On the third morning after his disappearance, however, he again showed himself in London, but this time not alone; for, to the amazement of every one, he entered the stable attended by the big mastiff from Kent. This great brute had no sooner arrived than he flew at the Newfoundland dog, who had so badly treated his little terrier friend, and a severe contest ensued, which the little terrier himself, seated at a short distance, viewed with the utmost dignity and

satisfaction. The result of the battle was, that the mastiff came off the conqueror, and gave his opponent a tremendous beating. When he had quite satisfied himself as to the result, this great avenger from Kent scarcely waited to receive the recognition of his master, who had been sent for immediately on the dog's arrival, but at once marched out of the stable, to the door of which the little terrier accompanied him, and was seen no more. Some few days afterward, however, the gentleman received a letter from his steward in the country, informing him of the sudden appearance of the terrier there, and his as sudden disappearance along with the large mastiff; and stating that the latter had remained away three or four days, during which they had searched in vain for him, but had just then returned home again. It then, of course, became quite clear that the little dog, finding himself unable to punish the town bully, had thought of his "big brother" in the country, had traveled over the sixty miles which separated them, in order to gain his assistance, and had recounted to him his grievance; it was plain also that the mastiff had consented to come and avenge his old friend, had traveled with him to London, and, having fulfilled his promise, had returned home, leaving the little fellow free from annoyance in the future.

The following well-known story is a strong example of the great intelligence which may be developed in a dog by careful training: A fashionably-dressed English gentleman was one day crossing one of the bridges over the Seine at Paris, when he felt something knock against his legs, and, looking down, he found that a small poodle-dog had rubbed against him, and covered his boots with mud. He was, of course, much annoyed, and execrated the little brute pretty freely; but when he got to the other side of the bridge, he had the boots cleaned at a stand for the purpose, and thought no more about the matter. Some days after this occurrence, however, he had occasion again to cross that bridge, and the same little incident occurred. Thinking this somewhat odd, he resolved to watch where the little dog went to; and, leaning against the side of the bridge, he followed with his eye the movements of his dirty little friend. He saw him rub against the feet of one gentleman after another, till he had exhausted all the mud off his once white skin, then rush off down the bank of the river, and there roll himself in the mud collected at the side. Having thus got a new supply of dirt, the little animal ran up to the bridge again, and proceeded to transfer it to the boots of the passers-by, as before. Having watched his movements for some time, the gentleman noticed that on one occasion, instead of running down to the river, he went off to the proprietor of the stand for cleaning boots, at the other end of the bridge, who received him very cordially. The truth then for the first time dawned on him, that the little animal belonged to the man who cleaned the boots, and was trained by him to perform these mischievous deeds, for the purpose of bringing in

custom. Being very fond of dogs, the Englishman resolved to purchase this clever little fellow, and bring him back to England with him. When, however, he went to the dog's master, that person at first denied any connection with him, and only admitted the ownership when he was perfectly satisfied that his interrogator had no connection with the police. For some time also he refused to part with the little poodle, saying that no money could pay him for the loss of his dog, who really made his living for him. Tempted, however, by a very high price, he at last consented to sell the dog; and the gentleman, a few days afterward, brought him over to England, traveling *via* Boulogne to Folkstone. His residence in England was some thirty or forty miles from Folkstone, and to this place he brought his little purchase. He had not been many days in his new home, however, when the little French poodle suddenly disappeared. Search was made for him everywhere, but to no effect. His new master offered a reward for him, but with the same result; and he had at last made up his mind that the little fellow had been either poisoned or stolen, when one morning, about six weeks after his mysterious disappearance, the gentleman received a letter from a friend in Paris telling him that his dog was back again there, and at his old trade of soiling boots in the interest of his former master. The little fellow, not liking the dullness of a country life, had resolved to return to his former home, and had made his way to Folkstone; there, as the gentleman afterward ascertained, he had got on board a steamer going to Boulogne, and from Boulogne had found his way back to Paris.

Of the foregoing three stories, the first two are probably even more remarkable than the last. The last (except as to the dog's finding its way back to Paris) illustrates only the possibility of developing in a dog, by the training of its natural intelligence, an almost human ingenuity. But it is by instilling into the dog the intelligence of a higher being that this skill is engendered. The spring of the intelligence is in the trainer, and it is to attain an object which the higher being, and not the lower, has in view. But in the first two cases the whole process is the dog's; the object to be secured, namely, revenge, is what the dog himself seeks, and the means by which that object is to be attained are devised and carried out by the instinct of the dog. That a dog should harbor revenge is, of course, not a very wonderful fact; but there is a calm reflection and a cool calculation displayed in the first two cases above given, which make them somewhat peculiar. If what we call instinct in these animals embraces powers so very like reason; if they are swayed by the same passions and affections which move us, and they are able to communicate to their fellows the feelings which stir them, and the external circumstances which bring those feelings into play, the border-line between man's mental territory and theirs becomes a little bit indefinite.—*Chambers's Journal.*

PROFESSOR HUXLEY'S LECTURES.[1]

II.

THE NEGATIVE AND FAVORABLE EVIDENCE.

IN my lecture on Monday night I pointed out that there are three hypotheses which may be entertained, and which have been entertained, respecting the past history of life upon the globe. According to the first of these hypotheses, life, such as we now know it, has existed from all eternity upon this earth. We tested that hypothesis by the circumstantial evidence, as I called it, which is furnished by the fossil remains contained in the earth's crust, and we found that it was obviously untenable. I then proceeded to consider the second hypothesis, which I termed the Miltonic hypothesis, not because it is of any particular consequence to me whether John Milton seriously entertained it or not, but because it is stated in a clear and unmistakable manner in his great poem. I pointed out to you that the evidence at our command as completely and fully negatives that hypothesis as it did the preceding one. And I confess that I had too much respect for your intelligence to think it necessary to add that that negation was equally strong and equally valid whatever the source from which that hypothesis might be derived, or whatever the authority by which it might be supported.

I further stated that, according to the hypothesis of evolution, the existing state of things was the last term of a long series of antecedent states, which, when traced back, would be found to show no interruption and no breach of continuity. I propose in this and a following lecture to test this hypothesis rigorously by the evidence at command, and to inquire how far that evidence could be said to be indifferent to it, how far it could be said to be favorable to it, and, finally, how far it could be said to be demonstrative. From almost the origin of these discussions upon the existing condition—and the causes which have led to it—of the animal and vegetable worlds, an argument has been put forward as an objection to evolution, which we shall have to consider very seriously. I think that that argument was first clearly stated by Cuvier in his criticism of the doctrines propounded by his great contemporary, Lamarck. At that time the French expedition to Egypt had called the attention of learned men to the wonderful stores of antiquities in that country, and there had been brought back to France numerous mummified corpses of animals which the ancient Egyptians revered and preserved, the date of which, at a reasonable

[1] The second of three lectures on "The Direct Evidence of Evolution," delivered at Chickering Hall, New York, September 20th. From the report of the *New York Tribune*, carefully revised by Prof. Huxley.

computation, cannot be placed at less than 3,000 or 4,000 years before the time at which they were thus brought to light. Cuvier endeavored to ascertain, by a very just and proper method, what foundation there was for the belief in a gradual and progressive change of animals, by comparing the skeletons and all accessible parts of these animals, such as crocodiles, birds, dogs, cats, and the like, with those which are now found living in Egypt, and he came to the conclusion —a conclusion which has been verified by all subsequent research— that no appreciable change had taken place in the animals which inhabited Egypt. And he drew thence the conclusion, and a hasty one, that this fact was altogether opposed to the doctrine of evolution. The progress of research since Cuvier's time has furnished far stronger arguments than those which he drew from the mummified bodies of Egyptian animals. A remarkable case is to be found in your own country in the neighborhood of the magnificent falls of Niagara. In the immediate vicinity of the whirlpool, and again upon Goat Island, in the superficial deposits which cover the surface of the soil of the rock in those regions, there are found remains of animals in perfect preservation—shells belonging to exactly the same forms as at present inhabit the still waters of Lake Erie. It is evident from the formation of the country that these animal remains were deposited in the beds in which they occur, at the time at which the lake extended over the region in which they are found. This involves the necessity that they lived and died before the falls had cut their way back through the gorge of Niagara; and, indeed, it is possible to determine that at that time the falls of Niagara must have been at least six miles farther down the river than they are at present. Many computations have been made of the rate at which Niagara is thus cutting its way back. Those computations have varied greatly, but I believe I am speaking within the bounds of prudence if I assume that the falls of Niagara have not retreated at a greater pace than about a foot a year. Six miles, speaking roughly, are 30,000 feet; 30,000 feet, at a foot a year, are 30,000 years; and we are fairly justified in concluding that no less a period than this has passed since these shell-fish, whose remains are left in the beds to which we have referred, were deposited. But there is even still stronger evidence of the long duration of certain types than this. As we work our way through the great series of the Tertiary formations, we find species of animals identical with those which live at the present day, diminishing in numbers, it is true, but still existing in a certain number in the oldest of the Tertiary rocks. And not only so, but when we examine the rocks of the Cretaceous epoch itself, we find the remains of some animals which the closest scrutiny cannot show to be in any respect different from those which live at the present time. That is the case with one of the lamp-shells, a *Terebratula* which is found in the chalk, and which has continued as it was found, or with insignificant variation,

through to the present day. Such is the case with the *Globigerinæ*, the skeletons of which, aggregated together, form the great mass of our chalk in England. That *Globigerina* can be traced down to the *Globigerinæ* which live at the surface of our great oceans, and the remains of which, falling to the bottom of the sea, give rise to a chalky material. So that it must be admitted that certain species of creatures living at the present day show no sign of modification or transformation in the course of a lapse of time as great as that which carries us back to the period of chalk. There are groups of species so closely allied together that it needs the eye of a naturalist to distinguish them one from another. If we pay attention to these, we find that a vastly greater period must be allotted, in some cases, to these persistent forms. In the chalk itself, for example, there is the fish belonging to the highest and the most differentiated of osseous fishes, which go by the name of *Beryx*. That fish is one of the most beautiful of fossils found in our English chalk. It can be studied anatomically, so far as the hard parts are concerned, almost as well as if it were a recent fish. We find that that fish is represented at the present day by very closely-allied species which are living in the Pacific and Atlantic Oceans. But we may go still farther back, and we find, as I mentioned to you yesterday, that the Carboniferous formations in Europe and in America contain the remains of scorpions in an admirable state of preservation, and those scorpions are hardly distinguishable from such as now live. I do not mean to say that they are not distinguishable, but they require close scrutiny to distinguish them from the scorpions which exist at the present day.

More than that. At the very bottom of the Silurian series, in what is by some authorities termed the Cambrian formation, where all signs of life appear to be dying out—even there, among the few and scanty animal remains which exist, we find species of molluscous animals which are so closely allied to existing forms that at one time they were grouped under the same generic name. I refer to the well-known *Lingula* of the *Lingula* flags, lately, in consequence of some slight differences, placed in the new genus *Lingulella*. Practically it belongs to the same great generic group as the *Lingula*, which you will find at the present day upon the shores of Australia. And the same thing is exemplified if we turn to certain great periods of the earth's history—as, for example, throughout the whole of the Mesozoic period. There are groups of reptiles which begin shortly after the commencement of this period, as the *Ichthyosauria* and the *Plesiosauria*, and they abound in vast numbers. They disappear with the chalk, and throughout the whole of that great series of rocks they present no important modifications. Facts of this kind are undoubtedly fatal to any form of the doctrine of evolution, which necessitates the supposition that there is an intrinsic necessity on the part of animal forms which once come into existence to undergo modifica-

tion; and they are still more distinctly opposed to any view which should lead to the belief that the modification in different types of animal or vegetable life goes on equally and evenly. The facts, as I have placed them before you, would obviously contradict directly any such form of the hypothesis of evolution as laid down in these two postulates.

Now, the service that has been rendered by Mr. Darwin in the doctrine of evolution in general is this: that he has shown that there are two great factors in the process of evolution: one of them is the tendency to vary, the existence of which may be proved by observation in all living forms; the other is the influence of surrounding conditions upon what I may call the parent form and the variations which are thus evolved from it. The cause of the production of variations is a matter not at all properly understood at present. Whether it depends upon some intricate machinery—if I may use the phrase—of the animal form itself, or whether it arises through the influence of conditions upon that form, is not certain, and the question may for the present be left open. But the important point is the tendency to the production of variations; then, whether the variations which are produced shall survive and supplant the parent, or whether the parent form shall survive and supplant the variations, is a matter which depends entirely on surrounding conditions. If the surrounding conditions are such that the parent form is more competent to deal with them and flourish in them than the derived forms, then, in the struggle for existence, the parent form will maintain itself and the derived forms will be exterminated. But if, on the contrary, the conditions are such as to be better for the derived than for the parent form, the parent form will be extirpated and the derived form will take its place.

In the first case, there will be no progression, no advance of type, through any imaginable series of ages; in the second place, there will be modification and change of form. Thus the existence of these persistent types of life is no obstacle in the way of the theory of evolution at all. Take the case of the scorpions to which I have just referred. No doubt, since the Carboniferous epoch conditions have existed such as existed when the scorpions of that epoch flourished, in which they find themselves better off, more competent to deal with the difficulties in their way than any kind of variation from the scorpion type; and for that reason the scorpion has persisted, and has not been supplanted by any other form. And there is no reason in the nature of things why, as long as this world exists, if there be conditions more favorable to scorpions than any variation which may arise from them, these forms of life should not persist.

Therefore, this objection is no objection at all. The facts of this character—and they are numerous—belong to that class of evidence which I have called indifferent. That is to say, they may afford no

direct support to the doctrine of evolution, but they are perfectly capable of being interpreted in consistency with it. There is another order of facts of the same kind, and susceptible of the same interpretation. The great group of *Lizards*, which abound so much at the present day, extends through the whole series of formations as far back as what is called the Permian epoch, which is represented by the strata lying just above the coal. These Permian lizards differ astonishingly little from the lizards which exist at the present day. Comparing the amount of difference between these Permian lizards and the lizards of the present day with the prodigious lapse of time between the Permian epoch and the present age, it may be said that there has been no appreciable change.

But when you carry your researches farther back in time you find no trace whatever of lizards nor of any true reptile whatever in the whole mass of formations beneath the Permian. Now, it is perfectly clear that if our existing paleontological collections, our existing species of stratified rock, exhaust the whole series of events which have ever taken place upon the surface of the globe, such a fact as this directly contravenes the whole theory of evolution, because this theory postulates that the existence of every form must have been preceded by that of some form comparatively little different from it. Here, however, we have to take into consideration that important fact so well insisted upon by Lyell and Darwin—the imperfection of the geological record. It can be demonstrated as a matter of fact that the geological record must be incomplete, that it can only preserve remains found in certain favorable localities and under particular conditions; that it must be destroyed by processes of denudation, and obliterated by processes of metamorphosis—by which I mean that beds of rock of any thickness crammed full of organic remains may yet, either by the percolation of water through them or the influence of subterranean heat (if they descend far enough toward the centre of the earth), lose all trace of these remains, and present the appearance of beds of rock formed under conditions in which there was no trace of living forms. Such metamorphic rocks occur in formations of all ages, and we know with perfect certainty when they do appear that they have contained organic remains, and that those remains have been absolutely obliterated.

I insist upon the defects of the geological record the more because those who have not attended to these matters are apt to say to us, "It is all very well, but, when you get into difficulty with your theory of evolution, you appeal to the incompleteness and the imperfection of the geological record;" and I want to make it perfectly clear to you that that imperfection is a vast fact which must be taken into account in all our speculations, or we shall constantly be going wrong.

You will all see that singular series of tracks which is copied of

its natural size in the large diagram hanging up here, which I owe to the kindness of my friend Prof. Marsh, with whom I had the opportunity recently of visiting the precise locality in Massachusetts in which these tracks occur. I am, therefore, able to give you my own testimony, if needed, that they accurately represent the state of

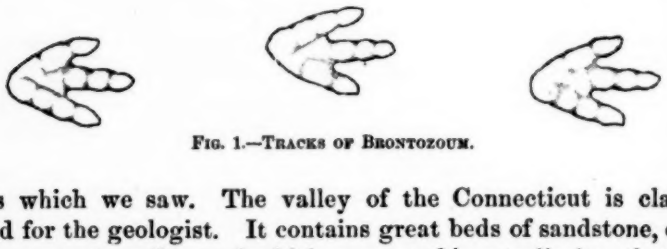


FIG. 1.—TRACKS OF BRONTOZOUM.

things which we saw. The valley of the Connecticut is classical ground for the geologist. It contains great beds of sandstone, covering many square miles, and which present this peculiarity, that they have evidently formed a part of an ancient sea-shore, or, it may be, lake-shore, and that they have been sufficiently soft for a certain period of time to receive the impressions of whatever animals walked over them, and to preserve them afterward in exactly the same way, as such impressions are at this very moment preserved on the shores of the bay of Fundy and elsewhere. We have there the tracks of some gigantic animal (pointing to the diagram), which walked on its hind-legs. You see the series of marks made alternately by the right foot and by the left foot; so that from one impression to the other of the three-toed foot on the same side is one stride, and that stride, as we measured it, is six feet nine inches. I leave you, therefore, to form an impression of the magnitude of the creature which must have walked along the ancient shore, and which made these impressions.

Now, of such impressions there are untold thousands upon these shores. Fifty or sixty different kinds have been discovered, and they cover vast areas. But up to this present time not a bone, not a fragment, of any one of the great creatures which certainly made these impressions has been found; and the only skeleton which has been met with in all these deposits to the present day—though they have been carefully hunted over—is one fragmentary skeleton of one of the smaller forms. What has become of all these bones? You see we are not dealing with little creatures, but animals that make a step of six feet nine inches; and their remains must have been left somewhere. The probability is, that they have been dissolved away, and absolutely lost.

I have had occasion to work at series of fossil remains of which there was nothing whatever except the casts of the bones, the solid material of the bone having been dissolved out by percolating water. It was a chance in this case that the sandstone happened to be of such a constitution as to set, and to allow the bones to be afterward dissolved out, leaving cavities of the exact shape of the bones.

Had that constitution been other than what it was, the bones would have been dissolved, the beds of sandstone would have fallen together, become one mass, and not the slightest indication that the animal had existed would have been discovered.

I know of no more striking evidence than this fact affords, of the caution which should be used in drawing the conclusion, from the absence of organic remains in a deposit, that animals did not exist at the time it was formed. I believe that, having the right understanding of the doctrine of evolution on the one hand, and having a just estimation of the importance of the imperfection of the geological record on the other, all difficulty from the kind of evidence to which I have adverted is removed; and we are justified in believing that all such cases are examples of what I have designated negative or indifferent evidence—that is to say, they in no way directly advance the theory of evolution, but they are no obstacle in the way of our belief in the doctrine.

I now pass on to the consideration of those cases which are not—for reasons which I will point out to you by-and-by—demonstrative of the truth of evolution, but which are such as must exist if evolution be true, and which therefore are, upon the whole, strongly in favor of the doctrine. If the doctrine of evolution be true, it follows that, however diverse the different groups of animals and of plants may be, they must have all, at one time or other, been connected by gradational forms; so that, from the highest animals, whatever they may be, down to the lowest speck of gelatinous matter in which life can be manifested, there must be a sure and progressive body of evidence—a series of gradations by which you could pass from one end of the series to the other. Undoubtedly that is a necessary postulate of the doctrine of evolution. But, when we look upon animated Nature as it at present exists, we find something totally different from this. We find that animals and plants fall into groups, the different members of which are pretty closely allied together, but which are separated by great breaks or intervals from other groups. And we cannot at present find any intermediate forms which bridge over these gaps or intervals. To illustrate what I mean: Let me call your attention to those vertebrate animals which are most familiar to you, such as mammals, and birds, and reptiles. At the present day these groups of animals are perfectly well defined from one another. We know of no animal now living which in any sense is intermediate between the mammal and the bird, or between the bird and reptile; but, on the contrary, there are actually some very distinct and anatomical peculiarities, well-defined marks, by which the mammal is separated from the bird, and the bird from the reptile. The distinctions are apparent and striking if you compare the definitions of these great groups as they now exist. At the present day there are numerous forms of what we may call broadly the pig tribe,

and many varieties of ruminants. These latter have their definite characteristics, and the former have their distinguishing peculiarities. But there is nothing that fills up the gap between the ruminants and the pig tribe. The two are distinct. So also is this the case between the groups of another class—reptiles. We have crocodiles, lizards, snakes, and tortoises, and yet there is nothing—no connecting link—between the crocodile and lizard, or between the lizard and snake, or between the snake and the crocodile, or between any two of these groups. They are separated by absolute breaks. If, then, it could be shown that this state of things was from the beginning—had always existed—it would be fatal to the doctrine of evolution. If the intermediate gradations which the doctrine of evolution postulates must have existed between these groups—if they are not to be found anywhere in the records of the past history of the globe—all that is so far a strong and weighty argument against evolution; while, on the other hand, if such intermediate forms are to be found, that is so much to the good of evolution, although, for the reason which I will put before you by-and-by, we must be cautious in assuming such facts as proofs of the theory.

It is a very remarkable fact that, from the commencement of the serious study of paleontology, from the time in fact when Cuvier made his brilliant researches upon the fossil remains of animals found in the quarries of Montmartre, Paleontology has shown what she was going to do in this matter, and what kind of evidence it lay in her power to produce.

I said just now that at the present day the group of pig-like animals and the group of ruminants are entirely distinct; but one of the first of Cuvier's discoveries was an animal which he called the *Anoplotherium*, and which he showed to be, in a great many important respects, intermediate in its character between the pigs on the one hand and the ruminants on the other; that, in fact, research into the history of the past did so far—and to the extent which Cuvier indicated—tend to fill up the breach between the group of ruminants and the group of pigs. All subsequent research has also tended in this direction; and at the present day the investigations of such men as Rütimeyer and Gaudry have tended to fill up and connect, more and more, the gaps in our existing series of mammals. But I think it may have an especial interest if—instead of dealing with these cases, which would require a great deal of tedious osteological detail—I take the case of birds and reptiles—which groups, at the present day, are so clearly distinguished from one another that there are perhaps no classes of animals which in popular apprehension are more completely separated. Birds, as you are aware, are covered with feathers; they are provided with wings; they are specially and peculiarly modified as to their anterior extremities; and they walk perpendicularly upon two legs; and those limbs, when they are considered anatomically,

present a great number of exceedingly remarkable peculiarities, to which I may have occasion to advert incidentally as I go on, but which are not met with even approximately in any existing forms of reptiles. On the other hand, reptiles, if they have a covering at all, have a covering of scales or bony plates. They possess no wings; they are not volatile, and they have no such modification of the limbs as we find in birds. It is impossible to imagine any two groups apparently more definitely and distinctly separated. As we trace the history of birds back in time, we find their remains abundant in the tertiary rocks throughout their whole extent, but, so far as our present knowledge goes, the birds of the tertiary rocks retain the same essential character as the birds of the present day—that is to say, the tertiary bird comes within the definition of our existing birds, and are as much separated from reptiles as our existing birds are. A few years ago no remains of birds had been found below the tertiary rocks, and I am not sure but that some persons were prepared to

FIG. 2.—HESPERORNIS REGALIS. (Marsh.)

demonstrate that they could not have existed at an earlier period. But in the last few years such remains have been discovered in England, though, unfortunately, in a very imperfect condition. In your

country the development of cretaceous rocks is enormous; the conditions under which the later cretaceous strata have been deposited are highly favorable to the preservation of organic remains, and the researches full of labor and toil, which have been carried on by Prof. Marsh in these Western cretaceous rocks, have rewarded him with the discovery of forms of birds of which we had hitherto no conception. By his kindness, I am enabled to place before you a restoration of one of these extraordinary birds, every part of which can be thor-

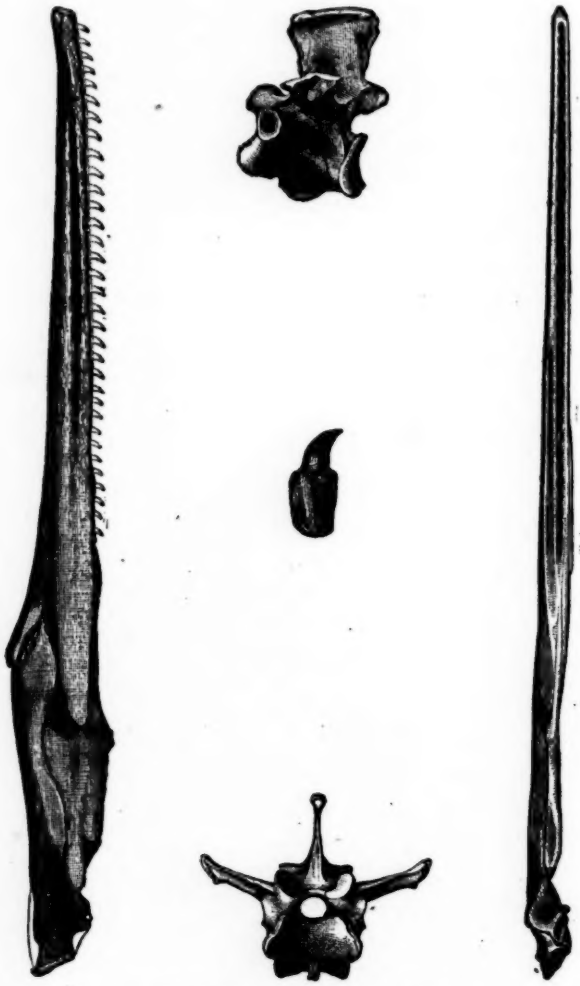


FIG. 3.—HESPERORNIS REGALIS. (Marsh.)

oughly justified. The remains exist in the greatest beauty in his collection. This *Hesperornis* stood about six feet high, and in a great many respects is astonishingly like an existing diver or grebe, so like

it indeed that, had this skeleton been found in a museum, I suppose—if the head had not been known—it would have been placed in the same general group as the divers and grebes of the present day. But this bird differs from all existing birds, and so far resembles reptiles in one important particular that it is provided with teeth. These

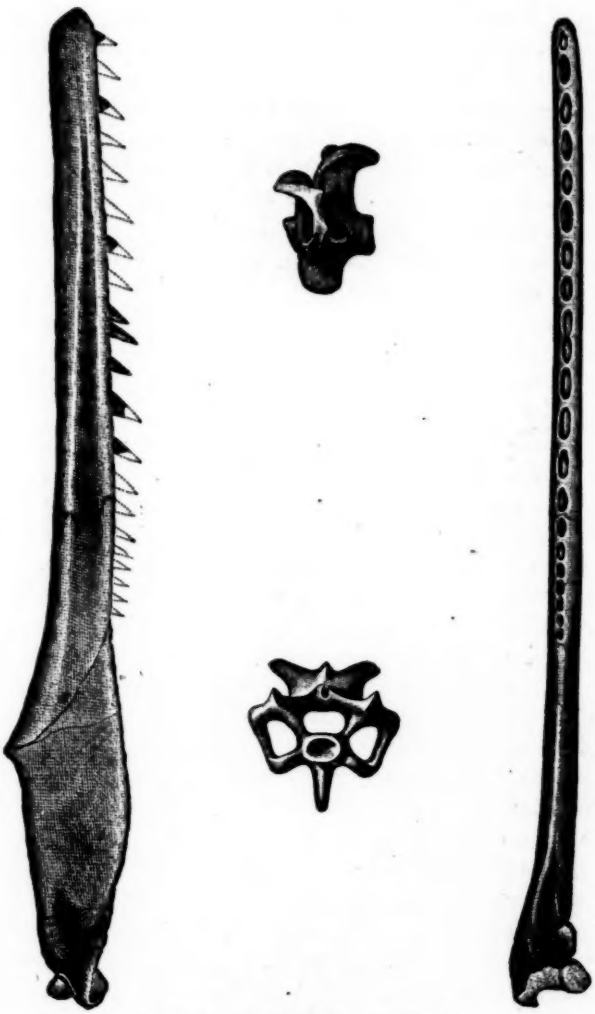


FIG. 4.—ICHTHYORNIS DISPAR. (Marsh.)

long jaws are beset by teeth, as in this diagram, in which one of the teeth is represented separately. In possessing true teeth, the *Hesperornis* differs entirely from any existing bird, and in view of the characteristics of this bird we are obliged to modify the definition of the class of birds and reptiles. Before the discovery of a creature such

as this, it might have been said that birds were characterized by the absence of teeth; but the discovery of a bird that had teeth shows at once that there were ancient birds that, in that particular respect, approached reptiles more nearly than any existing bird does.

The same rocks have yielded another bird (*Ichthyornis*), which also has teeth in its jaws, the teeth in this case being situated in distinct sockets, while those of *Hesperornis* were not so lodged. The latter also had very small wings, while *Ichthyornis* has strong wings. *Ichthyornis* also differed in the fact that the joints of its backbone—its vertebræ—had not the peculiar character that the vertebræ of existing birds have, but were concave at each end. This discovery leads us to make another modification in the definition of the group of birds, and to part with another of the characters by which they are distinguished from reptiles. We know nothing whatever of birds older than these until we come down to the Jurassic period, and from rocks of that age we have a single bird which was first made known by the finding of a fossil feather. It was thought wonderful that such a perishable thing as a feather should be discovered and nothing more, and so it was; and for a long time nothing was known of this bird except its feather. But, by-and-by one solitary specimen was discovered, which is now in the British Museum. That solitary specimen is unfortunately devoid of its head; but there is this wonderful peculiarity about the creature that, so far as its feet are known, it has all the characters of a bird, all those peculiarities by which a bird is distinguished from a reptile. Nevertheless, in other respects, it is unlike a bird and like a reptile. There is a long series of caudal vertebræ. The wing differs in some very remarkable respects from the structure it presents in a true bird. In a true bird the wing answers to these three fingers—the thumb and two fingers of my hand—the metacarpal bones are fused together into one mass—and the whole apparatus except the thumb is bound up in a sheath of integument, and the edge of the hand carries the principal quill-feathers. It is in that way that the bird's wing becomes an instrument of flight. In the *Archæopteryx*, the upper-arm bone is like that of a bird; these two forearm bones are more or less like those of a bird, but the fingers are not bound together—they are free, and they are all terminated by strong claws, not like such as are sometimes found in birds, but by such as reptiles possess, so that in the *Archæopteryx* you have an animal which, to a certain extent, occupies a midway place between a bird and a reptile. It is a bird so far as its foot and sundry other parts of its skeleton are concerned; it is essentially and thoroughly a bird in the fact that it possesses feathers, but it is much more properly a reptile in the fact that what represents the hand has separate bones resembling those which terminate the fore-limb of a reptile. Moreover, it had a long tail with a fringe of feathers on each side. All these cases, so far as

they go, you will observe are in favor of evolution to this extent, that they show that in former periods of the world's history creatures existed which overstepped the bounds of all existing classes and groups, and tended to fill up the intervals which at present exist between them. But we can go further than this. It is possible to fill up the interval between birds and reptiles in a much more striking manner. I do not think that this is to be done by looking upon what are called the *Pterodactyls* as the intermediate form between

FIG. 5.—PTERODACTYLUS SPECTABILIS. (Von Meyer.)

birds and reptiles. Throughout the whole series of the mesozoic rocks we meet with some exceedingly remarkable flying creatures, some of which attain a great size, their wings having a span of eighteen or twenty feet or more, and these are known as *Pterosauria*, or *Pterodactyls*. We find these with a bird-like head and neck, with a vertebral column sometimes terminated by a short and sometimes by a long tail, and in which the bones of the skeleton present one of the peculiarities which are often considered to be most characteristic of birds—that of having pneumatic cavities, which make

the creature specifically light in its flight. Like a bird, this creature has a largish breastbone, but from that point onward, so far as I can see, special, particular resemblances end, and a careful examination of the fore-limbs shows you that they are not birds' wings; they are something totally different from a bird's wings. And then, again (pointing to a chart), those are not a bird's posterior extremities, but are rather a reptilian's hind-limbs. The vertebræ present nothing that I need dwell upon, but the bones of the hand are very wonderful.

There are four fingers represented. These four fingers are large, and three of them—these, which answer to these three in my hands—are terminated by claws, while the fourth is enormously prolonged into a great jointed style. You see at once from what I have stated about a bird's wing that there could be nothing more unlike a bird's wing than this is. It was concluded by general reasoning that this finger was made to support a great web like a bat's wing. Specimens now exist showing that this was really the case, that this creature was devoid of feathers, but the fingers supported a vast web like a bat's wing, and there can be no doubt that this ancient reptile flew after the fashion of a bat. Thus, though the pterodactyl is a flying reptile, although it presents some points of similarity to birds, yet is it so different from them that I do not think that we have any right to regard it as one of the forms intermediate between the reptile and the bird. Such intermediate forms are to be found, however, by looking in a different direction. Through the whole series of mesozoic rocks there occur reptiles, some of which are of gigantic dimensions; in fact, they are reckoned among the largest of terrestrial animals. Some of them are forty and fifty, possibly more, feet long. Such are the *Iguanodon*, the *Megalosaurus*, and a number of others, with the names of which I will not trouble you. There are great diversities of structure among these great reptiles. Some of them resemble lizards in the proportions of their limbs, and have evidently walked on all-fours, in that respect resembling the existing crocodile; but in others you can trace a series of modifications in virtue of which the hind-limbs at length completely assumed the character of a bird's hind-limbs. I here indicate (pointing to a diagram) the hind limb of a crocodile, showing the bones of the hind-limbs and of the pelvis. These are the haunch-bones; these are the two leg-bones. Then comes the division of the foot which we call the tarsus, in which the component bones are separate and distinct from one another, from the bones of the leg and from those of the metatarsus. Then come the four toes, which alone exist in the hind-feet of the crocodile, and which are separate and distinct. The foot is flat on the ground, so that the legs spread out and the weight of the body hangs clumsily between them. Contrast this with what we find in the bird—the haunch-bone here is immensely elongated, and the joints of the

back-bone, between the two haunch-bones, are united so as to form a solid support upon which the weight of the body rests. Then the thigh-bone becomes very short, and has a back ridge upon its outer articular surface. At the lower end the ridge fits in between the upper extremity of the small bone of the leg, near to the great bone,

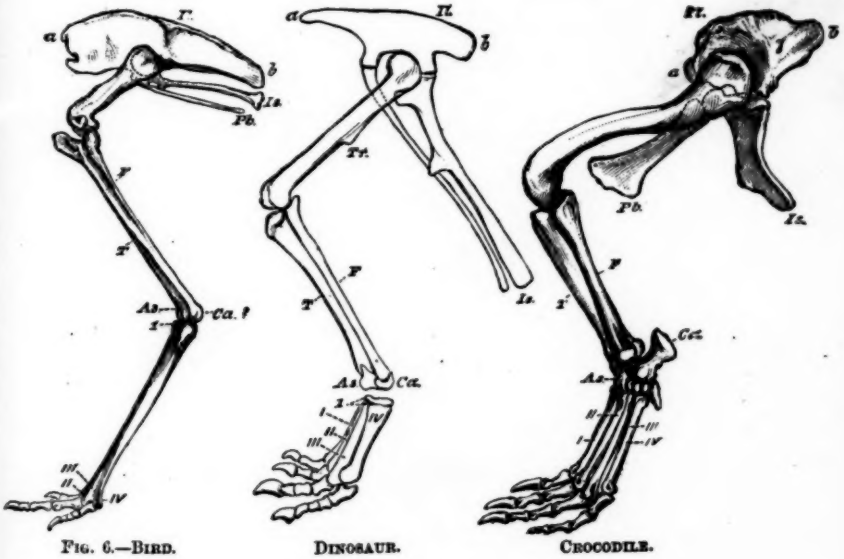


FIG. 6.—BIRD. DINOSAUR. CROCODILE.

and makes a kind of spring-joint. The small bone of the leg is quite large above, and becomes rudimentary below. It runs out into a style, instead of being long and large, as it is in the case of the crocodile. Then, when you come to the bones of the foot, you find there are no separate bones such as you have here, but the end of the tibia, or large bone of the leg, appears to end in a kind of pulley, a single bone follows the tibia and to the trifurcated extremity of this bone. Upon the extremity of that bone are attached three toes. It is obvious that the contrast between the crocodile's leg on the one hand, and the bird's leg on the other, is very striking. But this interval is completely filled up when you study the character of the hinder extremities in those ancient reptiles which are called the *Dinosauria*. In some of these the bones of the pelvis, and those of the hind-limb, become extraordinarily similar to those of birds, especially to those of young or fœtal birds. Furthermore, in some of these reptiles, the fore-limbs become smaller and smaller, and thus the suspicion naturally arises that they may have assumed the erect position. That view was entertained by Mantel, and was also demonstrated to be probable by your own distinguished anatomist, Leidy, but the discoveries of late years show that in some of these forms the

fact was actually so; that reptiles once existed which walked upon their hind-legs as birds now do. The diagram is a faithful and accurate representation of an existing fossil except for this, that, whereas in the existing fossil the bones are twisted about and out of place, I

FIG. 7.—COMPSOGNATHUS LONGIPES. (Wagner.)

have put them here in the position that they must have had in nature. You see a creature with a long neck and bird-like head, with very small anterior extremities, and that *compsognathous* creature must assuredly have walked about upon its hind-legs, bird-fashion. Add to this feathers, and the transition would be complete. Now to define it: The possession of teeth would, as we see, not separate this animal from the class of birds we have. We have had to stretch the class of birds so as to include birds possessed of teeth, and, so far as the character of the skeleton goes, we may fairly say that there needs here little more than the addition of feathers—and whether this creature had them or not we don't know—to convert it into a bird.

I have said that there can be no question, from their anatomical structure, that these animals walked upon their hind-legs, and, in fact, there are to be found in the Wealden strata of England gigantic footsteps arranged in order like these of the *Brontozoum*, and which there can be no reasonable doubt were made by *Dinosauria*, the remains of which were found in the same rock. And, knowing that reptiles that walked upon their legs and shared many of the anatomical characters of birds did once exist, it becomes a very important question whether those tracks in Massachusetts—to which I referred just now, and which formerly used to be unhesitatingly ascribed to birds—may not all have been made either by reptiles similar to the *Dinosauria*, or whether, if we could get hold of the skeleton which made these

tracks, some of which are marvelously like bird's tracks, we should not come upon exactly that series of transitions by which in former days the reptile was connected with the bird.

I don't think, ladies and gentlemen, that I need insist upon the value of evidence of this kind. You will observe that, although it does not prove that birds have originated from reptiles by the gradual modification of the ordinary reptile into a dinosaurian form, and so into a bird, yet it does show that such a process may possibly have taken place, and it does show that, in former times, there existed creatures which filled up one of the largest gaps in existing animate nature, and that was exactly the kind of evidence which I stated to you in starting we are bound to meet with in rocks if the hypothesis of evolution be correct.

In my third and last lecture I will take up what I venture to call the demonstrative evidence of evolution.

ON VARIATION IN THE MOTHS.

By AUG. R. GROTE, A. M.

THERE are a large number of different kinds of moths, inhabiting North America and Europe, which entomologists have classified under the technical family term, *Noctuæ*. Of this family, 1,028 different species have been catalogued as European. There being very many students, and a sufficient time having elapsed to secure a thorough collecting throughout the territory, this number may be taken as sufficiently corresponding with the actual representation of the family in Europe. In North America nearly 1,200 species are now catalogued,[1] but, since much of our territory remains to be explored in this respect, we may expect considerable additions to the number of known *Noctuæ* inhabiting our continent. The greater number of the species may be easily distinguished on comparison, the American from the European. There are, however, certain American species which differ but very slightly from certain European, and hence are generally called "representative species," or "species of replacement." For instance, *Apatela occidentalis* (G. and R.) "represents" the European *Apatela psi* (Linn.); *Agrotis Normaniana* (Grote), the European *Agrotis triangulum; Calocampa nupera* (Lintner), the European *Calocampa vetusta; Catocala relicta* (Walk.), the European *Catocala fraxini*, etc.

Although the number of such species appears relatively small,

[1] "List of the Noctuidæ of North America, 1875–'76." Buffalo, Reinecke & Zesch.

it is probably in reality larger than as yet suspected. For even the species acknowledged to occupy this relationship to each other exhibit quite different degrees of resemblance. I say "relationship," for we must reasonably conclude that this resemblance is not accidental or meaningless. It must indicate that both the European and American species are derived from a common stock. More than two years ago, I suggested that the faunæ had become separated through the physical action of the glacial epoch, showing that from the present distribution of species, and their degree of resemblance, no other hypothesis would explain all the facts in the case so satisfactorily. For we have to account, first, for the occurrence of nearly-related forms in localities as widely separated, geographically, as Texas and Germany; and then, again, for the occurrence, within our territory, of nearly-related species on the Alpine summits of Mount Washington and the distant arctic regions. The method of probable distribution of these latter species, through the action of the retreating ice, I have explained in the *American Naturalist* for March of this year.

In studying specimens of these related American and European species of *Noctuæ*, some new light bearing upon the question of their differences is attempted to be thrown in the present paper. I have endeavored to localize these differences upon some portion of the insect. In all the cases I have been able to investigate, these differences are expressed on the upper surface of the body and wings, and principally on the upper surface of the front pair of wings. Here it is that the first variations, which now have grown into specific differences, were probably expressed. And the reason for this seems to be, that this portion of the body is that usually exposed to the light and the action of external influences. The moths, during the daytime, rest with the front-wings dependent over the hind-wings, and nearly covering the body. While in the American and European related species the differences which lead us to call them distinct "species" are located on the front-wings chiefly, the under surfaces of both wings remain exceedingly similar in the contrasted forms. This is the portion which in the day time (the period of inaction for moths) is applied to the surface against which the insect rests, and is entirely shielded from exposure. Take, for instance, the European *Catocala fraxini* and the American *Catocala relicta*. The ground-color of the American species above and below is a bright, clear white. Now, beneath, both species show this color, but the upper surface of the fore-wings, in the European species, is obscured by an evenly-distributed admixture of blackish scales, so that the wings appear of a uniform obscure gray. The hind-wings, in the European species, are crossed by a band of bluish scales; in the American, this band is white, while I have recently detected a slight powdered edging of blue scales, difficult to perceive, and apparently hitherto unnoticed. The principal difference in ornamentation is, again, to be found on the

upper surface of the fore-wings. It lies in the course and shape of the transverse posterior line—a line which is a general feature of ornamentation throughout this group of insects.

This position might be sustained by parallel facts, but the limit of this article does not allow of their being presented. It remains to see what light these observations throw upon the origin of all these different kinds of moths. They seem to me to point to a method of variation in this group, and to a reason for its display. And, if we can apply these observations to particular instances, they may lead to a better understanding of the value of these specific forms, by allowing us to appreciate with more exactness the amount of differentiation they have undergone in the lapse of time. In a wider sense, we may attempt a classification by the ornamentation and coloration in the moths based on method, and such studies cannot fail to lend fresh interest to the barren but necessary work of describing the different species or forms. It seems to me, also, that these observations vindicate the importance of studying the characters of color and pattern in the group, and are, perhaps, a criticism on the remarks of those writers who purposely allow these no higher value than the subordinate one of dividing their material into "species" in their collections. In fact, these characters may give us a clew to the genealogy of the group, and seem to be of sufficient importance to be noted in descriptions of genera.

THE CONSTANCY OF MOTION.

By GEORGE ILES.

THE conservation of energy, as treated in the most recent work of authority on the subject, Prof. Balfour Stewart's, published in the "International Scientific Series," regards energy as divisible into two classes, actual and potential: actual energy, as in the case of a rushing stream of water, or a radiant and contracting mass of molten iron; and potential energy, where, for instance, a stone is at a height and may fall, or where a spring is tightly coiled and may unwind.

Prof. Stewart speaks the general opinion of modern physicists, Profs. Rankine, Tyndall, and others, when he states that, in cases of potential energy, the bodies endowed with it are absolutely at rest, and that the motion exhausted in storing up such energy is represented by a mere advantage of position, which, when utilized, yields in actual, palpable motion the energy which has lain completely quiescent, as when the stone falls to the earth, or the freed spring uncoils.

This division of energy into actual and potential seems to me to

be defective. It prevents the direct comprehension in the mind of energy as being motion and nothing else; it leaves unexplained how a body perfectly at rest can come to move; and further implies the dissipation of energy (which I have treated in a previous number of this journal) in a new phase, for, if all the actual energy in the universe were to become potential, all the real and positive motions which constitute life might indefinitely cease.

Let us examine, then, some cases of "potential" energy, and see if they be not actual, although under a disguise; so that the present definition of the conservation of energy may be replaced by the more intelligible statement that motion is constant; that it is never abolished for a time, nor absolutely suspended, all appearances to the contrary notwithstanding; and that so, all cases of energy are dynamic, and no part of them static, as now currently held.

For matter seemingly at rest may contain within itself motions as real as those to which at another time it openly gives rise, when it radiates heat or attracts by magnetism.

First of all, then, let us consider the case of a stone at a height, say on the brow of a cliff, capable of falling at any time when slightly pushed.

Gravity is the one force, of all the forms of energy, whose relations with others it is most difficult to imagine.

Other forces affect each other most palpably: magnetism forsakes a magnet when it is made white hot; chemical affinity is most sensitive to variations of temperature, and even in some cases to mechanical tremor; the transmission of electricity is favored by the cooling of a conductor, and so on.

Otherwise is it with gravity: a given mass of matter, however mechanically moved, electrified, magnetized, heated, or subjected to chemical changes, at the same point on the earth's surface, always weighs the same.

The only force with which gravity has any analogy is magnetism; and were magnetism always attractive, instead of polar, with equal opposite manifestations of attraction and repulsion, the analogy would be a strong one.

Let us, however, work out what analogy there is, and we may find that as the subtile movements of light were made plain by the study of the grosser movements of sound in air, so may the long-hidden laws of gravity be revealed in part, by tracing the similitude existing between their effects and those of common magnetism.

Both forces obey the law of squares: according to that law, they diminish as we recede from their centres of attraction. And what is very suggestive is, that, as their appetites are satisfied, they decrease in exactly the same ratio.

Two small magnets at a great distance from each other (so as to be practically out of the range of each other's influence), having each

a force equal to 1, when permitted to unite, have together a force less than 2; and this because work can be done by their attraction mechanically, or may appear as heat; and of course this must diminish their original stock of energy.

Precisely so with gravity. Suppose, for simplicity's sake, the radius of the earth to be 4,000 miles. Let us then imagine a stone of four tons lifted from the earth's surface to a distance of 4,001 miles; it would there weigh one ton—very nearly. Were such a mass to fall it would pass through 4,001 miles of space, and yield corresponding work.

Now let us further imagine a world, concentric with our present one, to be made up by the union of the earth with seven other such planets, and let us leave out of the question any possible condensation in the matter of this new world. Then supposing the stone to have resumed its former position in space, if gravity were allowed to act again, it could only do so through one mile, instead of 4,001 miles as before.

And mark how the geometrical necessities of enlargement lessen the working power of a mass attracting by gravity; for a stone weighing four tons on our present globe would only weigh twice as much on a sphere containing eight times the matter.

In the latter case, the surface would be twice as distant from the centre as in the former; for the attraction diminishes as the square of the distance of surface from the centre. Therefore the 8 times increased bulk has to be divided by 4, the square of the doubled radius.

Thus the weight of a definite mass on any celestial body varies as the density of the body and as the radius of it.

One of our pound-weights taken to the sun would there weigh 27 pounds, the sun's radius being about 110 times that of the earth, but its density only about one-fourth as great; while its bulk exceeds that of our planet by as much as 1,252,000 times.

If we now attentively observe the energy of a magnet in its usual genesis, we may learn somewhat, not only of gravity, but of attraction in general. The most convenient way to make magnets is by the use of an electric coil. A piece of properly-tempered steel is inserted in a helix of copper wire, through which a current circulates proceeding from the mechanical motion of a steam-engine, converted into electricity by suitable apparatus.

Other methods of magnetization there are, but none so directly instructive as this; here we have the visible, palpable motion of heavy wheels disappearing, and the chief result is the attractive force developed in the steel. The conviction dawns upon us that the motion of the wheels has been taken up by the molecules of the bar, that the steel has now internal movements which before it had not; and that these movements of its particles exist in full actuality, capable of doing tangible work when fitly permitted. Let us bring

a piece of iron or steel near to the magnet, and instantly it leaps toward it, confirming our conviction.

That a medium exists for the conveyance of such molecular motion, we are obliged to think; but what it is, or how it is affected, we cannot yet imagine. Thus much, however, is plain, that, as a medium purely, it can be no source of motion, so that the mere fact of distance between bodies can be no satisfactory explanation of attraction.

Attraction, then, wherever it appears, I believe to be due to contained motion in the particles of the bodies presenting it; which molecular motion is the equivalent of, and convertible into, the movement of masses as wholes.

Gravity, I venture to hold, is a force due to a distinct motion of the ultimate parts of matter, which has not yet been formulated. And, as the energy expended in sundering two united magnets reappears in the increase of their attractive powers, or the acceleration of such motion of their particles as constitutes magnetism, so the lifting of a stone from the earth would imply that the force consumed in so doing must take the form of a quickening in that motion of its particles which constitutes gravity. And we have seen how every successive act of obedience to both these forces of aggregation makes them weaker and weaker, as it reasonably should.

Therefore, I conclude that the energy of a stone at a height is not potential, but actual; that its value as a source of work, at any time, is represented by the swifter motion of its molecules as compared with those of a stone on the earth's surface; and that, as a stone falls, its internal motion takes the phase of mass motion.

This theory would lead us to suppose that the onward momentum of the planets, as they turn before the sun, is the expression of an equal internal gravitive motion of their ultimate parts, which exactly balances these mighty celestial revolutions.

The next case of "potential" energy to be inquired into is that of a coiled spring, which, in unwinding, may yield the force it took to coil it.

This case may be intelligibly explained on the same principle of the constancy of motion. The particles of a spring may be assumed to have a definite plane of molecular motion, which motion we shall presume is that due to temperature. In coiling, these planes are changed, and energy is required to do it; just as when a gyroscope-top is rapidly revolving in a certain fixed plane, it may, by a measurable effort, be made to revolve in a conical curve, with one end of its axis stationary, and the other describing a circle in space. And, as the gyroscope strongly tends to move in a uniform plane, and can do work in resuming such a plane, so I assume that the particles in a coiled spring have two similar motions, one of which is at any time available for tangible work when the spring is freed.

Yet another example. Let us take the case of a cylinder of compressed air which for years, tightly sealed, may serve as a store of force.

Prof. Clerk Maxwell explains how an ounce of air, in a closed and fragile jar, sustains the outside pressure of the atmosphere amounting to several tons; this he does by the theory that the ounce of air is made up of molecules which have so rapid a motion among themselves that they collide on the inside of the jar with as great a force as that of the atmospheric pressure externally.

This theory, now widely accepted, rests on the solid grounds of the measured velocity of air rushing into a vacuum, which is the same as that assumed for its internal motion; and further, on some observations of the diffusion of various gases into each other, which it would be out of place to detail here.

On the basis, then, of Prof. Maxwell's theory, we can believe that, in a cylinder of compressed air, the energy stored up exists in no merely "potential" form, but in the full actuality of the rapid motion of gaseous particles, which may take the shape of mass-motion when the piston is allowed to move outward.

An extension of the hypothesis that motion is continuous would lead to the inference that the so-called latent heat of water at 32° Fahr., as compared with ice at the same temperature, is due to the swifter movement of the molecules in the former case; and no facts are better known than that mechanical motion can become heat, and that heat turns ice into water.

Another implication of this theory is that atoms, as free hydrogen, oxygen, or carbon, are in exceedingly greater commotion than molecules, such as those of water or carbonic-acid gas. For the decomposition of such molecules may be effected by the exhaustion of mechanical motion, and I take it that the dynamic state of the products must balance this expenditure. What else can become of it?

The measure of the contained motion in two different atoms can be noted on their combining chemically, by the increase of temperature, which has its well-known mechanical equivalent.

The analogy between chemical units and small magnets is very close: as a magnet decreases in size, so, relatively thereto, does its attractive power increase; and, were we able to go on dividing until we came to a single atom of iron, we should doubtless have the magnetism merge into the equivalent phase of intense chemical affinity.

Without further illustration, then, of the principle set forth, I will say that, as in recent years we have had to familiarize ourselves with the idea that many forms of actual energy are impalpable, as the rays of light and the waves of sound, so now I think there are good grounds for extending our ideas so as to believe that all phases of "potential" energy are really actual; that, as we cannot but think

that only motion can breed motion, energy means motion; and that as such its amount is constant, and its presence, behind whatever veil, continuous; so that it is only properly divisible into two kinds, perceptible and imperceptible.

SKETCH OF PROFESSOR MAYER.

AMONG the younger physicists of the country who have done honor to American science by the interest and extent of their original researches, the subject of the present sketch, and of whom we give an excellent portrait this month, holds a distinguished place. Though now only in the prime of his manhood, he has already made many refined and elaborate experimental researches, by which he is widely and favorably known to men of science both in this country and in Europe.

ALFRED MARSHALL MAYER was born in Baltimore, November 3, 1836. His grandfather, Christian Mayer, was descended from an ancient family in the city of Ulm, Würtemberg, and came to Baltimore when a young man. Here he made a large fortune in trade with India and Mexico. He was well known in his day for his liberal and elegant hospitality, his extensive reading, profound knowledge of mercantile law, and those marked social and gentlemanly traits that made him a delightful companion. His father was Charles F. Mayer, who was distinguished for his learning, eloquence, and extensive literary culture. He is the nephew of Brantz Mayer, a prominent writer, who is especially known by his various valuable works on Mexico, where he resided for a time as secretary of legation.

Prof. Mayer was partly educated at St. Mary's College, in Baltimore, which he left at the age of sixteen for a more practical sphere of study. He entered the workshop and draughting-room of a mechanical engineer, where he remained two years, acquiring a knowledge of the use of tools, mechanical drawing, the method of constructing machines, and careful mechanical manipulation. Subsequently, during two years, he cultivated analytical chemistry by thorough laboratory practice.

Prof. Mayer has occupied the chair of Physics, with Chemistry and Astronomy, in several colleges, as follows: University of Maryland, 1856–'58; Westminster College, Missouri, 1859–'61; Pennsylvania College, Gettysburg, 1865–'67; Lehigh University, Bethlehem, Pennsylvania, 1867–'70; and the Stevens Institute of Technology since 1871. In 1863–'64 he studied physics, mathematics, and physiology, in the University of Paris.

Prof. Mayer's first contribution to science was made in 1855, and

described in a paper in the *American Journal of Science and Arts*, entitled "A New Apparatus for the Determination of Carbonic Acid," which was republished in Germany. His second paper was on the estimation of weights of very small portions of matter, in which he showed that, by the deflections of fine glass fibres, we can weigh a particle of matter as small as the $\frac{1}{1000}$ of a milligramme. While at the Lehigh University, he designed and superintended the erection of an astronomical observatory, put together and adjusted the instruments, and made a series of observations on the planet Jupiter, which were republished in England. He was in charge of the party sent by the United States Government to observe the eclipse of the sun at Burlington, Iowa, August 7, 1869, and took forty-one perfect photographs of the eclipse with exposures lasting only the $\frac{1}{500}$ of a second.

While at the Lehigh University, Prof. Mayer contributed to the *American Journal of Science and Arts* and the *Journal of the Franklin Institute* various original contributions on the "Solar Protuberances," "Spectral Analysis of the Stars," "Physical Constitution of the Sun," "Electro-Magnetism," "Electric Conductivities," "On the Alleged Electro-Tonic State," "Magnetic Declination in Connection with the Aurora," "Photographing the Magnetic Spectra;" and at the Salem meeting of the American Association he read an instructive paper "On the Thermo-Dynamics of Waterfalls." He had taken the temperatures of the water at Trenton and Niagara before it leaps the cataract and after it strikes below. According to theory, when the falling motion is arrested, it is converted into heat, and should be shown in a rising temperature below. The observations indicated that the effects of evaporation and contact of the divided water with the air were greater than the impact in changing the temperature of the fallen water, so that it may be actually colder below than above. But on days when the air is saturated with moisture, and the temperatures of the water and air are about the same, results were obtained which show that the warming of the falling water conforms to Joule's law of the conversion of motion into heat.

Since entering upon his duties at the Stevens Institute of Technology, notwithstanding the labor of lecturing and teaching which the position involves, Prof. Mayer has conducted elaborate investigations in various branches of physics, which have given to science many new and important results. Among these may be mentioned researches in magnetism, heat, and especially "On the Effects of Magnetization in changing the Dimensions of Iron and Steel Bars," and "On the Isothermals of the Solar Disk." We cannot here give the particulars of these interesting inquiries, but must refer the reader to the memoirs in the scientific journals.

The line of investigation, however, to which Prof. Mayer has mainly devoted himself within the last few years is that of acoustics

in its various physical connections, and especially in relation to the theory of music. These researches are described in papers contained in the *American Journal of Science and Arts*, and several of his important conclusions have been incorporated in the English edition of Helmholtz's "Sensations of Tone as a Physiological Basis for a Theory of Music." Mr. Alexander J. Ellis, F. R. S. (the translator of the above work), has also recently published a lecture which he delivered before the London Musical Association, on the application of Prof. Mayer's discoveries to the elucidation of the fundamental principles of musical harmony.

The chief claims of Prof. Mayer in regard to his recent acoustical results may be concisely summed up as follows:

1. He discovered that, by using the phenomena of sympathetic vibration, one can show that the translation of a vibrating body causes it to give sonorous waves, differing in length from those produced by the same vibrating body when stationary.

2. He first succeeded in actually detecting the different phases of vibration *in the air surrounding a sounding body*, and thereby measured the lengths of its waves; and first experimentally explored in the free air the exact form of any wave-surface; and he has determined the forms of these envelopes around a sounding body with as much facility as one can obtain the form of the surface of a palpable body *in the dark*.

3. He devised a simple and accurate method of measuring the wave-lengths of sound in air and in gases, and was the first to measure with precision the relative intensities of sounds by means of manometric flames.

4. He first approximately determined the mechanical equivalent of an aërial sonorous vibration.

5. He obtained in an experiment all the conditions required in "Fourier's theorem," and thus first gave an exact experimental confirmation of it.

6. He has devised and used *five* new methods of sonorous analysis for the decomposition of a compound sound into its elementary simple tones. He also first, by means of a rotating disk, reproduced the vibratory motions of a molecule of air, when it is animated with the resultant action of the six elementary vibrations forming a musical note.

7. He first discovered, by delicate experiment, that the fibrils of the antennæ of the male mosquito vibrate sympathetically to notes which have the range of pitch of the sounds given out by the female mosquito. He also showed first how an insect may determine the direction of sounds by means of his antennæ.

8. He discovered that the terminal auditory nerve-fibrils vibrate half as often in a given time as the membrane of the tympanum and

the ossicles of the ear, and proposed on these facts a new hypothesis of the mode of audition.

9. He first discovered the law connecting the pitch of a sound with the time that the sensation of the sound endures after the air has ceased to vibrate the tympanic membrane. This law rendered the qualitative results of Helmholtz quantitative; and in the third edition of Helmholtz's "Tonempfindungen" Mr. Alexander J. Ellis, as noted above, has extensively used this law as the only basis for reaching exact quantitative results in the fundamental phenomena of musical harmony. This law Prof. Mayer has applied extensively to the elucidation of the fundamental facts of harmony, and to the explanation of many obscure phenomena in the physiology of hearing.

10. He discovered that sonorous sensations interfere with one another, and that, although a low sound may entirely obliterate the sensation of a sound *higher* in pitch, yet a sound cannot in the slightest obliterate the sensation of another sound *lower* than it in pitch. He has made applications of these discoveries in showing that a radical change is required in the usual method of conducting orchestral music, and in a new method of determining the relative intensities of sounds.

11. He has determined with great precision the laws of the vibrations of tuning-forks, especially in the direction of the bearing of these laws on the action of chronoscopes used in determining the velocities of projectiles. He first accurately gave the correction to be applied in all such determination on account of the different temperatures of the forks.

Besides these difficult and delicate original investigations, Prof. Mayer has contributed numerous articles to Appletons' and Johnson's "Cyclopædias" in his more especial lines of inquiry, and has written much for various popular publications. He was one of the editors of the *American Journal of Science and Arts*, but reluctantly gave up its duties in 1873 on account of weakness of sight. He then suspended work, and went to England for a vacation, where he was cordially received and kindly entertained by his brethren of the various scientific societies.

CORRESPONDENCE.

FIGHT BETWEEN A TROUT AND A WATER-SNAKE.

To the Editor of the Popular Science Monthly.

HAVING read in your July number Mr. Buckland's account of a fight between a scorpion and a mouse, I am induced to give you an account of a remarkable conflict between a large water-snake and a trout, witnessed by myself and one of my brother officers in the survey in 1867, on the Purissima, a small trout-stream which empties into the ocean about twenty-four miles south of San Francisco. We had been fishing on the stream, and came to a high bank which overlooked a transparent pool of water about ten feet in diameter and four feet in depth. This pool was fringed with willows, and had on one side a small gravel-bank. The trout at first sight was lying in mid-water, heading up-stream. It was, as afterward ascertained, fully nine inches in length, a very desirable prize for an angler. While studying how to cast our flies to secure him, a novel fisherman appeared, and so quick were his actions that we suspended our own to witness them. This new enemy of the trout was a large water-snake of the common variety, striped black and yellow. He swam up the pool on the surface until over the trout, when he made a dive, and by a dexterous movement seized the trout in such a fashion that the jaws of the snake closed its mouth. The fight then commenced. The trout had the use of its tail and fins, and could drag the snake from the surface; when near the bottom, however, the snake made use of its tail by winding it around every stone or root that it could reach. After securing this tail-hold it could drag the trout toward the bank, but, on letting go, the trout would have a new advantage. This battle was continued for full twenty minutes, when the snake managed to get its tail out of the water and clasped around the root of one of the willows mentioned as overhanging the pool. The battle was then up, for the snake gradually put coil after coil around the root, with each one dragging the fish toward the land. When half its body was coiled it unloosed the first hold and stretched the end of its tail out in every direction, and, finding another root, made fast, and now using both dragged the trout out on the gravel-bank. It now had it under control, and, uncoiling, the snake dragged the fish fully ten feet up on the bank, and I suppose would have gorged him. We killed the snake, and replaced the trout in the water, as we thought that he deserved liberty. He was apparently unhurt, and in a few moments darted off. That the water-snake of our California brooks will prey upon the young of trout and also smaller and less active fishes, I have noticed, but never have seen an attack on a fish so large or one more hotly contested. Yours respectfully,

A. W. CHASE,
Assistant U. S. Coast Survey.

EDITOR'S TABLE.

THE NEW YORK AQUARIUM.

THE devotees of rational amusement, the lovers of natural history, and the friends of scientific education, in this city, are to be congratulated on the establishment of the aquarium which was recently completed and opened to visitors. Undoubtedly the devotees of rational amusement are not so numerous as they might be, but they will increase in numbers as increasing facilities are afforded for combining agreeable recreation with instructive observation in the acquisition of pleasant knowledge without much trouble. As a means of increasing the general taste in natural history, and affording students the opportunity of familiarizing

themselves with forms of life hitherto inaccessible and known chiefly in books, the aquarium is invaluable, and will be a great help in promoting the work of science. The museum shows us dead specimens, stuffed, dried, and variously preserved, and is of course not without interest. But the aquarium opens to us the living, moving curiosities and wonders that are nowhere else to be seen. What the menagerie is to the creatures of the forest, the desert, and the prairie, the aquarium is to the tenants of the lake, the river, and the ocean. But, while land-animals have long been captured and collected for inspection, the aquarium is a new and recent affair, involving great difficulties in its successful management. These difficulties can only be overcome at large expense, by persevering experience, and through special and thorough knowledge of the conditions of life of an immense variety of aquatic creatures. The opportunity such an establishment opens to the scientific observer, investigator, and experimenter, should be highly prized, and we have no doubt it will be well appreciated by this class of students.

In an educational point of view, or as a means of popular instruction, a well-stocked aquarium cannot fail to be of the highest value. Natural history is a growing subject in our schools, but is so generally pursued merely from text-books which give no real knowledge, that a great available museum of living objects is precisely what is wanted to give reality and efficiency to this branch of study. The New York Aquarium should be brought into very close relations with the common-school system of the city. We are glad to observe that this element of its usefulness has not been overlooked in the plan and management of the enterprise. Provisions for study, instruction, and systematic observation have been incorporated with it, and this feature has been held so important as to be placed in special charge of a cultivated naturalist. Mr. W. S. Ward, who has been abroad this season and visited the chief aquariums of Europe, with a view of acquiring information that will be valuable to the scientific management, will devote himself to the educational service of the institution.

It is a noteworthy fact that we are indebted for the New York Aquarium entirely to private enterprise. There was talk that the city would establish something of the kind in the Central Park; but it came to nothing, and, after the municipal fizzle over the fossil restorations undertaken by Mr. Waterhouse Hawkins, we may conclude that it was perhaps best that the city did not undertake this work. But what it was unable or disinclined to do has been projected and carried out by the persevering enterprise of Mr. W. C. Coup, who has devoted his energy to its organization, and risked his money upon his chance of success. The aquarium is an honor to this metropolis and promises a large benefit to the public, and it should be liberally patronized and well sustained. We have no doubt it will meet from all classes with the encouragement it certainly deserves.

A CASE IN MENTAL PHYSIOLOGY.

An account comes to us of an enterprising Englishwoman who was equal to the following exploits in sharp practice: "By a series of the most extraordinary misrepresentations and cleverly carried out impostures, she raised large sums of money on no security whatever, and spent them as recklessly; imposed on jewelers so that they trusted her with goods worth many hundreds of pounds; furnished grand houses entirely at the expense of trusting upholsterers; introduced herself by sheer impudence to one great nobleman after another, and then introduced her dupes, who, on the faith of those distinguished

social connections, at once disgorged more money. To one person she was a great literary character; to another, of royal descent; to another she had immense expectations; to another, she was a stern religionist."

This woman must have been as smart as she was unscrupulous. Her capacity of imposture was as marked as the deficiency of moral sense; she was as shrewd and long-headed as she was knavish. The art of her conduct, the consummate calculation, and the skillful adaptation of means to ends in dealing with others, implicate the whole intellectual sphere of action which was at the same time exempt from the control of conscience. Yet the force of moral considerations was implied throughout as she had to deal with people who were influenced by them, and to give good reasons for her various claims and representations. It was a sufficiently obvious case of cool criminal depravity, and most people would have little difficulty in deciding what was to be done about it. But current theories of conduct stop with mental *effects*. Mind being regarded as having a sphere of its own, and the mental world being held as an independent world, where all that goes on is purely psychical, there is no interest or requirement to look beyond the open manifestations of mind to their causes in another sphere. If we should say that this woman had something more than a mind, something more than an immaterial responsible soul, that we must look deeper than the mental manifestations displayed in conduct, that she had a brain made up of cells, fibres, tissues, and circulating blood, subject to the laws of nutrition, waste, and repair, debility, degeneration, and disease, and that all these things must be taken into account as controlling conditions of mental effects, we should be met immediately by the cry of *materialism!* And if we should furthermore say that these three or four pounds of nervous matter must come into consideration before society can proceed to decide upon such a case, a cry of denunciation would be raised against a destructive materialism that threatens to subvert the order of society.

Nevertheless, the question of mind in this case was an organic problem of the brain, as the further facts will show. This woman had lived a quiet but honest and uneventful life up to the time that she suddenly struck out into her sensational career. A year of lying, cheating, and scheming practices ended in the development of marked insanity and brain-disease, when she was taken to the Royal Edinburgh Asylum for the Insane, where she soon died. The victims of her cunning and mendacity were simply the dupes of a lunatic, and the question of her character and accountability resolves itself into a problem of brain-derangement, of morbid material conditions, and is therefore a question of practical materialism which the physician cannot escape.

EVOLUTION AND THE COPERNICAN THEORY.

It is significant that nearly all the divines who have spoken, in reply to Prof. Huxley, commit themselves to some form of the doctrine of Evolution. While, however, they admit that there is *some* truth in it, there is a common protest against the idea that it contains *much* truth—not by any means so much as is claimed by Prof. Huxley. He said that the evidence for it is demonstrative, and that it is as well based in its proofs as the Copernican theory of astronomy. This is thought to be quite absurd. It is said that Huxley may know a great deal about animals and fossils, but that obviously he knows very little about logic. His facts being admitted, a great deal of effort has been expended to show that he does not understand how to reason from them.

The Rev. Dr. William M. Taylor, in a letter to the *Tribune*, takes up Prof. Huxley on this ground, and is quite shocked at his logical incapacity. The following is a sample passage from his communication, and a very fair example, besides, of the sort of comment which his lectures have elicited:

"Indeed, to affirm, as he did, that evolution stands exactly on the same basis as the Copernican theory of the motions of the heavenly bodies, is an assertion so astounding that we can only 'stand by and admire' the marvelous effrontery with which it was made. That theory rests on facts, presently occurring before our eyes, and treated in the manner of mathematical precision. It is not an inference made by somebody from a record of facts, existing in far-off and prehistoric, possibly also prehuman ages. It is verified every day by occurrences which happen according to its laws. But where do we see evolution going on to-day? If evolution rests upon a basis as sure as astronomy, why do we not see one species passing into another now, even as we see the motions of the planets through the heavens? . . . We know that astronomy is true, because we are verifying its conclusions every day of our lives on land and on sea. We set our clocks according to its conclusions, and navigate our ships in accordance with its predictions, but where have we anything approaching even infinitesimally to this, with evolution?"

The author of this passage is said to be a man of eminence and ability. That may be, but he certainly has not won his distinction either in the fields of logic, astronomy, or biology. When a man undertakes to state the evidence of a theory, and gives us proofs that equally sustain an opposite theory, we naturally conclude that he does not know what he is talking about. This is very much Dr. Taylor's predicament. In trying to contrast the evidence for evolution with the demonstrative proofs of the Copernican theory, he cites facts that are not only as good, but far better, to prove the truth of its antagonist, the Ptolemaic theory.

Dr. Taylor talks as if the Copernican theory is something that anybody can see by looking up into the sky, but the case is far from being so simple. The Copernican theory of the planetary motions assumes that they take place around the sun as their centre; the Ptolemaic theory taught that the earth is the stationary centre of the system, and that the sun, moon, and planets, revolve around it. We must not forget that the Ptolemaic theory was the fundamental conception of astronomy, and guided its scientific development for two thousand years. It was based on extensive, prolonged, and accurate observations; was elucidated and confirmed by mathematics—geometry, and trigonometry; and was verified by confirming the power of astronomic prevision. The planetary motions were traced and resolved on this theory with great skill and correctness, elaborate tables being constructed which represented their irregularities and inequalities, so that their future positions could be foretold, and conjunctions, oppositions, and eclipses, predicted. It embodied a great amount of exact knowledge, and was capable of taking in and preserving all the new results of the labors of a long series of Greek, Latin, Arabian, and modern European astronomers. Dr. Whewell says of it: "In this sense, therefore, the Hipparchian theory was a real and indestructible truth, which was not rejected, and replaced by different truths, but was adopted and incorporated into every succeeding astronomical theory, and which can never cease to be one of the most important and fundamental parts of our astronomical knowledge."

Copernicus, then, did not abolish but rather revised the old astronomy. He accepted the whole system of eccentrics and epicycles, and, so far as planetary motions are concerned, he simply recentred the solar system. He showed that the evidence in favor of that view preponderated, and his theory was a victory of refined, remote, and indirect investigation.

Dr. Taylor tells us that the Copernican theory "rests on facts presently occurring before our eyes." So does the Ptolemaic theory; and not only that, but, if the test is what occurs before our eyes, then the Ptolemaic theory is a thousand times stronger than the Copernican. If the Copernican theory is so obvious, if it "rests on facts presently occurring before our eyes," why did the astronomers of twenty centuries fail to discern it? Why could not the divines of Copernicus's time see it when it was pointed out to them? And why could not Lord Bacon admit it a hundred years after Copernicus? Dr. Taylor says, "It is verified every day by occurrences that happen according to its laws." So was its opposite, the Ptolemaic theory. Our reverend logician says, furthermore: "We know that astronomy is true, because we are verifying its conclusions every day of our lives, on land and on sea. We set our clocks according to its conclusions, and navigate our ships in accordance with its predictions." And all this they did with the astronomy that preceded Copernicus. Yet the author of this rubbish airs his logical pretensions, and talks about the "effrontery" of Prof. Huxley. Where is his shame?

The Copernican theory is held as demonstrably true, but it is not because everybody can see the demonstration. There was demonstrated truth in the opposite theory, though the proof was not so complete. And in regard to this matter of demonstration, of which so much is said, we have to remember that evidence is a thing of degrees. There may be evidence for a proposition which is so small that we hardly regard its truth as possible—we do not believe it. There is a grade of proof that amounts to probability, but leaves us in uncertainty. There are higher degrees of proof that confer assured belief, and leave little room for doubt. There is, again, evidence so perfect and decisive as to give certainty of conviction, and this we call demonstration. And evidence may have a yet higher shade of intensity, as where we cannot even conceive the opposite of a proposition to be true, and this may be characterized by the frequent expression, "absolute demonstration." The best examples of demonstration are furnished by mathematics in consequence of the fewness and simplicity of mathematical ideas, but demonstration by no means necessarily involves mathematics. There is plenty of demonstrated truth that is not mathematical. The anatomist demonstrates his science by observation, and the chemist by experiment. Fossils found in the rocks demonstrate that life existed upon the globe before the rocks were formed; and the vestiges of art found in Western mounds demonstrate that a race of men superior to the savages formerly lived upon this continent. A theory is said to be demonstrated when it brings all the known facts into agreement, explains them, excludes all other interpretations, and is consistent with itself and all that is understood of the ways of Nature. Most theories of the operations of Nature have about them traces of the imperfection that belongs to all things human, difficulties that are still unresolved, while yet the evidence for them may be so overwhelming as to be held demonstrative.

How is it, now, with the proof of the theory of Evolution, which assumes that the immense diversity of living forms now scattered over the earth has arisen through a long process of gradual unfolding and derivation, within the order of Nature, and by the operation of natural laws? It involves and is built upon a series of demonstrated truths. It is a fact accordant with all observation, and to which there never has been known a solitary exception, that the succession of generations of living things upon earth is by reproduction and genetic connection in the regular order of Na-

ture. The stream of generations flows on by this process, which is as much a part of the settled, continuous economy of the world as the steady action of gravity or heat. It is demonstrated that living forms are liable to variations which accumulate through inheritance; that the ratio of multiplication in the living world is out of all proportion to the means of subsistence, so that only comparatively few germs mature, while myriads are destroyed; that, in the struggles of life, the fittest to the conditions survive, and those least adapted perish. It is a demonstrated fact that life has existed on the globe during periods of time so vast as to be incalculable; that there has been an order in its succession by which the lowest appeared first, and the highest have come last, while the intermediate forms disclose a rising gradation. It is a demonstrated truth of Nature that matter is indestructible, and that therefore all the material changes and transformations of the world consist in using over and over the same stock of materials, new forms being perpetually derived from old ones; and it is a fact now also held to be established, that force obeys the same laws. All these great truths harmonize with each other; they agree with all we know of the constitution of Nature; and they demonstrate evolution as a fact, and go far toward opening to us the secondary question of its method.

The reverend writer, whom we have quoted, asks, "If evolution rests on a basis as sure as astronomy, why do we not see one species passing into another now, even as we see the motions of the planets through the heavens?" To this foolish question, which has nevertheless been asked a dozen times by clerical critics of Huxley, the obvious answer is, that what requires a very long time to produce cannot be seen in a very short time. Has the writer ever seen the production of a geological formation? That he has not seen the evidences that would have prevented him from asking such a question is probably because he is not a student of Nature, and has not looked for them.

There has been much complaint that Prof. Huxley undertook to put the demonstrative evidence of evolution on so narrow a basis as the establishment of the genealogy of the horse, but this rather enhances than detracts from his merit as a scientific thinker. It has been well remarked that "the genius of the discoverer appears in his perceiving how small a number of facts, rightly considered, are sufficient to form a foundation for a theory." Kepler had to fix but a few points in the path of Mars, to demonstrate the ellipticity of his orbit, and to subvert the theory of circular planetary motions, by which the way was paved to the Newtonian astronomy. Prof. Huxley could have accumulated a far more striking display of the proofs of evolution for a popular audience, but he preferred to rest the question on evidence that was none the less decisive because it was restricted. If the horse has been derived from preceding forms in the way he pointed out, then that is the method of Nature—unless we deny the unity of its order.

And here is the vital point between Prof. Huxley and his antagonists. It is a question of the validity of the conception of the order and uniformity of Nature. Prof. Huxley holds to it as a first principle, a truth demonstrated by all science, and just as fixed in biology as in astronomy. His antagonists hold that the inflexible order of Nature may be asserted perhaps in astronomy, but they deny it in biology. They here invoke supernatural intervention. Obviously there are but two hypotheses upon the subject, that of the genetic derivation of existing species, through the operation of natural law, and that of creation by miraculous interference with the course of Nature. If we assume the orderly course of Nature, development

is inevitable; it is evolution or nothing. If the order of Nature is put aside and special creation appealed to, we have a right to ask on what evidence? It was long maintained that the universe was made in a week, by a quick succession of divine fiats. This view is now abandoned, and it is maintained, *as a new theory*, that the millions of species which science has proved to have appeared all along the course of geological time were also the products of miraculous agency. But, as logic has been appealed to, we again press the question, on what evidence? There is no evidence. There is not a scintilla of proof that can have a feather's weight with any scientific mind. We are told that each link in the chain of ancestry of Prof. Huxley's horse was a special creation. But who tells us this, and what do they know about it? Genetic derivation is in the field as a real and undeniable cause; but what possible ground is offered for the alternative supposition? Has anybody ever seen a special creation? Do those who believe in it represent to themselves any possibility of how it could have occurred? Milton attempted to form an image of the way the thing was done, and says that the animals burst up full-formed and perfect like plants out of the ground—"the grassy clods now calved." But clods can only calve miraculously. Nature does not bring them into the world now by this method, and science certainly can know nothing of it. So far from being possible, so far from being probable, so far from being proved, this hypothesis of the origin of animal forms is simply unthinkable; it is a violation not only of the order of Nature, but of the very conditions of thought. From this point of view, therefore, the theory of evolution differs from the Copernican theory by having no alternative possibility. The Copernican theory was but the revision and modification of a preceding theory which had evidence in its favor, and could be rationally held by scientific minds; the evolution theory has a force of demonstration derived from the fact that the only alternative view cannot for a moment be entertained by any mind that recognizes the logical force of scientific evidence; in this respect, therefore, the evidence for evolution is even stronger than that for the Copernican theory.

LITERARY NOTICES.

THE THEORY OF SOUND IN ITS RELATION TO MUSIC. By PIETRO BLASERNA, of the Royal University of Rome. With numerous Illustrations. Pp. 187. Price, $1.50. International Scientific Series, No. XXII.

NOTHING could be more appropriate than that the first Italian contribution to the "International Scientific Series" should take up one of the most interesting relations of science to art. Italy has been long preeminent as the land of artistic genius, although her distinction has been chiefly won by cultivating the arts that appeal to the eye—painting, sculpture, and architecture. Germany leads in the modern development of musical art, and her great physicist, Helmholtz, stands first as the elucidator of the laws of sound applied to musical science. But the great work of Helmholtz is a sealed book to the people. Prof. Blaserna has been first to take the brilliant results of recent acoustical progress and apply them to musical art and theory in so clear and familiar a manner that common readers will follow him with ease and pleasure.

The work is addressed both to scientific students and to musicians, but it is properly a contribution to the science of music. It does not at all cover the ground of Prof. Tyndall's volume on "Sound," which is strictly a text-book of acoustics, but, starting with so much of acoustical principles as is necessary for his purpose, Prof. Blaserna devotes the work to those scientific elucidations of musical art and practice which will have the greatest interest to those concerned in musical study. We cannot better give account of the volume than by quoting freely from the admira-

ble review of it that has just appeared in the London *Lancet*. The writer says: "This work is an attempt to popularize the theory of music, and so to combine the theoretical with the practical study of this art that instrumentalists may obtain some knowledge of those fundamental laws of sound on which music is based. With this object in view Prof. Blaserna commences his treatise by explaining the laws of vibrations of strings and pipes, and shows how such vibrations may be measured; he then explains the theory of music in reference to the consonant and dissonant intervals, pointing out how the various ratios in the octave have been introduced, together with the nature of the perfect major and minor chords, the inversion of which, he observes, constituted the principal resource of Palestrina and of the composers of his school. This leads him to speak of dissonances, and of the nature of the musical scales. An exceedingly interesting *résumé* is then given of the history of music from the earliest period to the present day. In the music of all nations, Prof. Blaserna remarks, two unfailing characters are found —rhythmic movement and procedure by determinate intervals. The former appertains to many of the actions of man, but the second belongs exclusively to music. The instrument of Orpheus, however powerful its effects may have been in rendering inanimate objects 'sequacious of the lyre,' was but a poor instrument, consisting only of the following four notes: C, F, G, and the octave C. It is remarkable that this scale contains the most important musical intervals of declamation, the voice rising a fourth in making an interrogation, another a fifth higher in emphasizing a word, while in ending a story it falls a fifth. In speaking of Greek music he explains the difference between the Pythagorean and the modern scale. The ancient Scotch and Chinese scale, in which an enormous number of popular songs are written, consists of a succession of fifths, B*f*, F, C, G, D.

"The inventor of the modern system of musical notation was Guido d'Arezzo, and by him and Josquino and Orlando Tasso polyphonic music underwent great development. Then came the Reformation, and church music was greatly simplified to enable the whole congregation to join in it. An elaborate discussion of the characters of the major and minor scales succeeds, with an account of the effects of transposition. The temperate scale in common use is then explained, and its imperfections are declared to be so manifest that the author expresses a hope it will eventually be abolished. It is, in fact, only maintained by the piano-forte, which is essentially the instrument of the temperate scale, and the defects of which have greatly tended to obscure pure melody. The quality or timbre of musical sounds, both vocal and instrumental, is then referred to, and the methods of investigating the vibrations are given, as well as the laws of harmonics and chords. Finally, Italian and German music are compared. The influence of Paris on music, though the French have never been creators, is defined as insisting on the creation of a type of music which should contain the good points of the German and Italian schools without their exaggeration. It has maintained the Italian melody and song, but has also adopted the grand choral and orchestral movements of Germany."

THE RACES OF MAN AND THEIR GEOGRAPHICAL DISTRIBUTION. By OSCAR PESCHEL. Translated from the revised German edition. New York: D. Appleton & Co. Pp. 528. Price, $2.25.

THE students of ethnology are to be congratulated on the appearance in English of this admirable manual of ethnological and ethnographical science, which has for some years and in its successive editions been a standard in Germany. While the work is full and systematic, it is at the same time compact and convenient for reading, being a happy medium between the bulky and formidable treatise, and the deficient and unsatisfying compend. Dr. Peschel's work has the great merit of being up to date in the presentation of an extensive and rapidly-developing branch of science, and of dealing fully with those recent and highly-important questions concerning the science of man which have come forward into such prominence in our own generation. The book is exactly what readers of general cultivation require to inform themselves upon a subject of great moment, and which is occupying the close attention of thinkers

in all nations; and it will also be of a special value to the scientific students of ethnology, not only for the breadth and care of its discussions, and the immense amount of information condensed in its text, but also for the copious wealth of its references to the literature and authorities of the subject.

No just idea of its broad range of interesting topics pertaining to the nature, characters, habits, and diversities of man, can be conveyed in a brief notice of the work. But, as its materials are derived from the most instructive portions of history, from the descriptions of races furnished by travelers, from wide geographical observation, and from the various sciences which illustrate the constitution of man and his intercourse with surrounding Nature, the facts brought forward have a very wide diversity of interest, so that we cannot dip into the volume anywhere without becoming quickly absorbed in the question under consideration.

The book is divided into two parts. In the introduction to the first part the author devotes himself to the question of man's place in creation, of the unity or plurality of the human race, of the place of its origin and the problem of its antiquity; then follows a series of disquisitions on the physical characters and the linguistic characters of man, and the industrial, social, and religious phases of his development. The second part is descriptive of the races of mankind, which are taken up in their leading divisions, and in their geographical distribution, and considered with as much detail as the limits of the work will allow. The book, of course, has nothing like the comprehensiveness or strictness of method and classification that characterizes Mr. Spencer's great work, "Descriptive Sociology;" nor has it the depth and completeness of analysis of social phenomena that mark the "Principles of Sociology" by the same author; but, as a *résumé* of the subject in a single handy volume, we have probably nothing so good in the language.

REPORT OF THE GEOLOGICAL SURVEY OF OHIO. Published by authority of the Legislature of Ohio. 4 vols. Columbus: Nevins & Myers, State Printers.

THE first geological information obtained concerning the State of Ohio was derived from a report made by a committee which took its observations in the summer of 1836. Geology was then a science in a preliminary stage of development, and the application of the existing knowledge was impeded by ignorance of the general outlines of the country. Paleontology was in much greater obscurity, and it is natural that the report of that period should seem imperfect at the present time.

In March, 1869, the Legislature passed a bill authorizing a complete survey of the State by a committee of competent men. In addition to a minute geological investigation, they were to make a careful chemical analysis, including a classification of the various soils, and the best means for promoting their utility; and were to take observations to determine the local causes producing variations of climate, etc.

The officers appointed were Prof. J. S. Newberry, chief geologist; Edward Orton and E. B. Andrews, assistant geologists; T. G. Wormley, chemist; F. B. Meek, paleontologist, besides a number of local assistants. They entered upon their work June 1, 1869, and finished it June 1, 1874, at a cost of $256,000, including the publication of four volumes of reports. For rapidity of action, thoroughness of results, and moderation in the expense, this survey contrasts most favorably with those made in other States. Thus far there have been published two volumes on geology and two on paleontology, with maps of some of the counties. In the volumes on paleontology there are a large number of plates and illustrations, which are admirable specimens of careful work and beauty. Ohio is rich in fossil remains, having contributed largely to the cabinets of other States, and this is the first occasion on which they have been presented to the public. The plan of the corps was to publish six volumes, two on geology, two on paleontology, one on economic geology, and one on zoölogy, botany, and agriculture. The last two volumes have not yet been published, though the work of composition is far advanced.

Surveys had been made previous to this one in many of the other States, which presented discrepancies that had given rise to much bitter discussion. It was, therefore, of importance that Ohio should be thoroughly explored, as it formed the key-

stone in the arch reaching from the Alleghanies to the Mississippi, and offered the probable means of solving the perplexing difficulties.

According to Prof. Newberry, "the topographical features may be described as those of a plain slightly raised along a line traversing it from northeast to southwest, and worn in the lapse of time by the draining streams into broad valleys, which impart a pleasing variety to the surface, afford free and healthful drainage, and yet leave unimpaired all the productiveness of its original monotony; in fact, exhibiting perhaps the most perfect adaptation to the wants of man which any surface affected by such climatic influences can present." The climate is one of extremes. The soil over much more than half the State is of foreign origin, being transported by Drift agencies frequently from a great distance. The physical substructure is not simple like the surface, but is diversified in different places, both as to the number, character, and thickness of the strata, and the position which they occupy relative to each other and to the horizon. The coal-measures underlie the surface of the southeastern third of the State, there being an aggregate of about 12,000 square miles over which the coal is unequally distributed. All the coals are classed as bituminous, and are divided into dry or furnace coals, coking-coals, and cannel-coals, by far the greater portion being of the coking variety. It is proposed to discuss the distribution, qualities, and uses of the coals in the volume on economic geology.

MANUAL OF THE VERTEBRATES OF THE NORTHERN UNITED STATES, including the District east of the Mississippi River and north of North Carolina and Tennessee, exclusive of Marine Species. By DAVID STARR JORDAN, M. S., M. D., Professor of Natural History in N. W. C. University, and in Indiana State Medical College. Chicago: Jansen, McClurg & Co. 12mo, pp. 342. Price, $2.00.

THE object of this work is to facilitate the classification of vertebrate animals by means of artificial keys, such as have been used in the study of botany. It has been prepared for the use of collectors and students who are not specialists, and has been compressed within the narrowest limits in order to render it as cheap a handbook as possible. There are descriptions of 817 species, representing 116 families. It is the only work containing arranged descriptions of the reptiles and fresh-water fishes of this country.

THE CENTENNIAL SITUATION OF WOMAN. A Commencement Address at Mount Holyoke Seminary, by Hon. ALEXANDER BULLOCK. Charles Hamilton, Worcester, Massachusetts. Pp. 45.

GOVERNOR BULLOCK made an eloquent speech to the South Hadley ladies, but whether he was quite equal to the occasion may be a question depending upon the view taken of the duties of such an opportunity. Some may think that, in reviewing a hundred years of progress in public or social affairs, it is most suitable to take note of what has been gained; to dwell upon the triumphs, the causes of congratulation, and give indulgence to the more complacent feelings. Others may regard it as the most fitting time to be on our guard against this ever-besetting tendency, the time to survey closely and critically the position that has been reached, to sift current claims, to look sharply after mistakes, and utilize an impressive occasion to forecast the best course of action for the future. Governor Bullock took the most agreeable alternative, and discoursed pleasantly, and with commendable gallantry, of what woman has done to improve her condition in various ways, and what civilization has accomplished for her in furtherance of the same end. He points out the progress that woman has made toward the independence of self-dependence through the opening to her of modern industries; sketches the changes that have taken place in the recognition of her civil rights; and dwells upon the great advance that has been made in the work of female elevation, and in opening to woman a wide opportunity in the vocation of teaching. He touches lightly the vexed question of the intellectual equality of the sexes, saying it has been settled that there is no question at all about it, and deftly quotes a woman—Mrs. Jameson—as expressing the opinion that "the intellect of woman bears the same relation to that of man as her physical organization; it is inferior in power and different in kind. In men the intellectual facul-

ties exist more self-poised and self-directed, more independent of the rest of the character, than we find them in women, with whom talent, however predominant, is in much greater degree modified by the sympathies and by moral causes." The Governor evades the question of suffrage for woman, but is adverse to her participation in public affairs. He cites Franklin as saying that "women should not meddle with party politics, except in the endeavor to reconcile their husbands, brothers, and friends, who happen to be of contrary sides;" and he reminds the listening ladies of the pleasantry of Addison, who remarked: "There is nothing so bad for the face as party zeal. It gives an ill-natured cast to the eye, and a disagreeable sourness to the look; besides that, it makes the lines too strong, and flushes them more than brandy."

THE KINEMATICS OF MACHINERY: Outlines of a Theory of Machines. By F. REULEAUX, Member of the Royal Trade Commission. Translated and edited by ALEXANDER B. W. KENNEDY, C. E., Professor of Civil and Mechanical Engineering in University College, London. With numerous Illustrations. London: Macmillan & Co. Pp. 622. Price, $7.50.

THE number of inventions during recent years has been so great that it is almost impossible to classify the different machines, or to observe any regular system connecting them. This country possesses no systematized instruction or extended literature in regard to machinery, and, although it has been peculiarly rich in inventions, the results would undoubtedly have been more satisfactory if they had been effected according to an arranged method. In this book the theoretical part of machinery alone is treated. The author attempts to give a thorough understanding of its essential nature, by which problems previously unsolvable may be made clear, and by which greater practical results may be reached. In his own words, his purpose is "to determine the conditions which are common to all machines in order to decide what it is, among its great variety of forms, that essentially constitutes a machine. . . . The book is intended, not so much to add to the positive knowledge of the mechanician, as to increase his understanding of what he already knows, so that it may become more 'thoroughly his own property.'" In the old books, each machine was taken up as a whole, and treated by itself. But, as it was discovered that similar parts occur in different machines, the method continually grew more simple. Prof. Reuleaux endeavors to place the science in a position in which it may become deductive, and in which the study may depend upon a few fundamental truths. With him, motion is but a change of position, and the changes are conditioned simply by the geometric form of the moving bodies.

In this volume fluids also take their place as forming a part of machinery, and instances are given in what forms engineers may use them to the greatest advantage. The work, which was written in German, has been published in Italian, and is now being translated into French.

THE ETHICS OF BENEDICT DE SPINOZA. From the Latin, with an Introductory Sketch of his Life and Writings. New York: Van Nostrand. Pp. 375. Price, $3.00.

THIS volume has a peculiar interest in being the first American translation of the "Ethics" offered to the public. As it has been preceded by only one English translation, the book will supply a want in this country, and meet the demand of those who desire to obtain a clear idea of Spinoza's philosophy. The object which Spinoza had, in developing his system, was to discover certain rules by which he might govern his own actions. To accomplish this, he begins with a number of definitions and axioms from which his principles are evolved in regular geometrical order. The work is divided into five parts. In the first part is set forth his conception of God—an absolutely Infinite Being or substance, without beginning or end, and *causa sui*. Nothing can be thought of outside of God, and everything which exists does so through God. In the second part are treated the origin and nature of the human mind and soul. In the third, fourth, and fifth parts, an investigation is made of the passions, their causes and effects, their force and the manner in which they should be governed. The end arrived at is, that the pleasures of

sense and intellect should balance each other, and in this manner the greatest happiness be secured. Thus, by a different process of reasoning, he arrives at a result similar to that reached by the Christian religion. Whatever may be thought of this as a religious or logical system, yet, taken as a whole, it is a work of the purest morality. The "Ethics" is the product of the reasoning powers and not of the imagination. Its general style and literary character are at great variance with the smooth disquisitions of modern times, but, if these mechanical effects are overlooked, the thoughtful reader will find the truths as new and striking as when they were first written.

In the preface is given an outline of the author's life, with the effect produced by his writings. The translation has been made with care and skill, and differs from the English translation in being somewhat more concise, while it is at the same time equally clear.

COMPARATIVE ZOÖLOGY, STRUCTURAL AND SYSTEMATIC. For Use in Schools and Colleges. By JAMES ORTON, A. M., Professor of Natural History in Vassar College; Corresponding Member of the Academy of Natural Sciences, Philadelphia, and of the Lyceum of Natural History, New York; author of "The Andes and the Amazon," etc. New York: Harper & Brothers, 1876. Price, $3.00.

THIS volume, as we are informed by the author in the preface, is "designed solely as a manual for instruction, and to present clearly, and in a somewhat new form, the established facts and principles of zoölogy." It is claimed for it "that the selection and arrangement of essential principles and typical illustrations are from the standpoint of the teacher. . . . and that a distinctive character of the work consists in treating of the whole animal kingdom as a unit, and in the comparative study of the development and variation of organs and functions from the simplest to the most complex state."

The work is divided into two parts, the first of which treats of structure, the second of systematic zoölogy, the plan of the author being to withhold from students the study of the classification of animals until "they have mastered those structural affinities upon which true classification is founded."

In both divisions of the work the synthetic method is employed, as being the most natural one, a study of simple structures and forms being first introduced.

The plan of the work is comprehensive, and claims to represent the latest phases of the science of zoölogy. Comparative zoölogy is defined as "the comparison of the anatomy and physiology of all animals existing and extinct, to discover the fundamental likeness underneath the superficial differences, and to trace the adaptation of organs to the habits and spheres of life."

The style is usually clear and attractive, and the book may be read with interest and profit by others than teachers and students. But we notice some passages which are obscure from brevity, others from inadvertence; and there are several inaccuracies, all of which it will be found more easy to correct in a second edition than it was to avoid in the first.

One feature of the work will neither be overlooked nor excused by naturalists. Of about 350 illustrations, a very large number, probably 300, are old, and have done service several times before. If some of these cuts are excellent and appropriate, others could have been omitted without detriment, while new ones illustrating American types are needed.

The value of the work is enhanced by copious notes, 220 in number, at the close of the volume.

WHAT YOUNG PEOPLE SHOULD KNOW. The Reproductive Function in Man and the Lower Animals. By BURT G. WILDER. With Twenty-six Illustrations. Boston: Estes & Lauriat. Pp. 212. Price, $1.50.

PROF. WILDER, being convinced that there are greater evils caused by ignorance of the legitimate and illegitimate uses of the reproductive organs than by the perversion of any other human propensity, has written this book to dispel the ignorance. If there were real knowledge upon such subjects, he thinks there would be no exercise of the imagination in regard to them. Few will agree with him in this idea, however excellent his work may be as a physiological treatise for the young in this special branch.

PRACTICAL BOTANY, STRUCTURAL AND SYSTEMATIC, ETC. By AUGUST KOEHLER, M. D., Professor of Botany in the College of Pharmacy of the City of New York. Copiously illustrated. New York: Henry Holt & Co. 12mo, pp. 400. Price, $3.00.

THE author, believing that "the study of botany cannot become truly profitable until a number of plants have been identified by the student, and their images received into his memory," has constructed a book which is an artificial key to "stimulate the unlearned," and act as a labor-saver to those already somewhat acquainted with the science. It departs from the ordinary system of classification, in being arranged according to the old dichotomal method. The natural tendency of this might, perhaps, be to suggest names rather than the association of principles. Those, however, who are desirous of rapid action, and speedy results, will find here a book for their purpose in a neat and convenient form.

THEORY OF MEDICAL SCIENCE: The Doctrine of an Inherent Power in Medicine a Fallacy. The Ultimate Special Properties of Vitality and the Laws of Vital Force constitute the Fundamental Basis of Medical Philosophy and Science. By WILLIAM R. DUNHAM, M. D. Boston: James Campbell. Pp. 150. Price, $1.25.

THE title-page speaks for itself, and indicates the theory on which this book was written. The work was published with the hope that it might recover the "fundamental principles involved in a correct theory of medical science," assist the profession in the details of practice, and enable the non-professional to distinguish between quackery and rational practice. The author finds fault with the medical profession because it continues to follow the ancient interpretations of the science, but seems unwilling himself to adopt the results of those who are doing most for the furtherance of correct principles in regard to mind and body.

CALIFORNIA NOTES. By CHARLES B. TURRILL. San Francisco: Bosqui & Co. Price, $1.50.

THE "Notes" is a description or guide through different sections of California, in which the author conducts his readers to the places visited by him. Among the subjects represented in the book are, "San Francisco," "Into the Heart of the Foot-Hills," "Calaveras County," "Gold-Mines," "The Yosemite Valley," etc. This volume is the initial number of a series.

ELEMENTS OF PHYSICAL MANIPULATION. By EDWARD C. PICKERING, Thayer Professor of Physics in the Massachusetts Institute of Technology. Part II., pp. 316. Price, both parts, $4.00.

THIS second volume, like the first, is designed as a special text-book for the laboratory. The text is made up principally of experiments, giving a description of the instruments to be used, and a plan of what is to be done. Among the subjects discussed are "Electricity," "Meteorology," and "Astronomy." The latter is a new feature in laboratory practice, but there is no reason why it should not be taught practically, as well as chemistry or physics.

PUBLICATIONS RECEIVED.

The Religion of Evolution. By M. J. Savage. Pp. 253. Boston: Lockwood, Brooks & Co. Price, $1.50.

The Symbolical Language of Art and Mythology. By R. P. Knight. Pp. 267. New York: J. W. Bouton. Price, $3.00.

Essays on Mind, Matter, Forces, etc. By Charles E. Townsend. Pp. 404. New York: Somerby.

Chemia Coarctata. By A. H. Kollmyer. Pp. 111. Philadelphia: Lindsay & Blakiston. Price, $2.25.

Matter and Force. By J. K. Macomber. Pp. 100. Ames, Iowa: Agricultural College print.

Ancient Pagan and Modern Christian Symbolism. By Thomas Inman, M. D. Pp. 187. New York: Bouton. Price, $3.00.

Elementary Hand-book of Applied Mechanics. By W. Rossiter. Pp. 150. New York: Putnams. Price, 75 cents.

Elementary Hand-book of Theoretical Mechanics. Pp. 146. Same author and publisher. Price, 75 cents.

Geological Survey of Indiana (1875).

By E. T. Cox. Pp. 600. *Indianapolis Sentinel* print.

Public Libraries in the United States. Part I., pp. 1222; Part II., pp. 89. Washington: Government Printing-Office.

Essays in Literary Criticism. By R. H. Hutton. Pp. 344. Philadelphia: J. H. Coates. Price, $1.50.

Vaccination as a Preventive of Smallpox. By W. C. Chapman, M. D. Pp. 91. Toledo, Ohio: Brown & Faunce.

German and American Brewers' Journal. Semi-monthly. $5.00 per year. Brewers' Publishing Company, 20 Park Place, New York.

On Cephalization. By James D. Dana. Part V., pp. 7. From *American Journal of Science and Arts.*

Report of the Condition of the Academy of Natural Sciences of Philadelphia. By W. S. W. Russhenberger. Pp. 56. Philadelphia: Collins print.

Essential Piety of Modern Science: a Sermon. By J. W. Chadwick. Pp. 31. New York: Somerby.

Surface Drainage of the Metropolitan (Boston) District. By C. W. Folsom, C. E. Pp. 4. From Report of Massachusetts Board of Health.

A List of Orthoptera. By Dr. Cyrus Thomas. Pp. 20. From Proc. D. A. N. S., vol. i.

American Library Journal. Monthly. Pp. 27. $5.00 per year. New York: Leypoldt.

MISCELLANY.

Distribution of Plain, Prairie, and Forest.—In the *American Naturalist* for October, Prof. J. D. Whitney gives a very elaborate critique of the various hypotheses which have been put forth to account for the distribution of plain, prairie, and forest, over the North American Continent. The author has no theory of his own to offer, but he appears to show conclusively that none of the accepted theories can be regarded as satisfactory. One of the theories examined by Prof. Whitney is that which attributes the existence of forest, prairie, or plain, to the distribution of rainfall throughout the year, or from season to season. As stated by the late J. W. Foster, this theory holds that "wherever the moisture is equable and abundant, we have the densely-clothed forest; wherever it is unequally distributed, we have the grassy plain (prairie); and where it is mostly withheld, we have the inhospitable desert." This last proposition Prof. Whitney admits, the other two he pronounces erroneous. He cites the vicinity of Chicago, where Mr. Foster lived, in proof of the incorrectness of that author's views. "Here," says Prof. Whitney, "we have the finest prairie-regions in the world, absolutely destitute of trees, and yet in the full enjoyment of an abundant precipitation, and in the immediate vicinity of an immense sheet of water. For Chicago itself, indeed, the statistics of rainfall are very defective, but, such as they are, they are entirely unfavorable to Mr. Foster's hypothesis. Points in the immediate vicinity of that city, where observations have been taken for a series of years, show an average rainfall of thirty-six to fifty inches, pretty uniformly distributed through the year. An excellent instance, on the other hand, of a dense growth of trees combined with the most unequally-distributed rainfall which is possible, is furnished by the western slope of the Sierra Nevada, in California, whose magnificent forests are well known, as also is the fact that there is no precipitation there at all for six months of the year, nearly the whole of the rainfall being limited to three months. And, lest it may be thought that melting snow keeps the ground moist during the summer, it may be added that the heaviest forest-belt of the Sierra is quite below the line above which snow rests for any considerable time, and that the soil in that belt is usually perfectly dry at the surface, and even dusty, for six months of the year, and often much more."

Electrical Phenomena exhibited by Venus's Fly-Trap.—The electrical phenomena exhibited by *Dionæa muscipula* have been investigated by Dr. Burdon-Sanderson, who finds that normally the whole leaf with the petiole is somewhat negative, but, when excited by a stimulus, an electrical

change takes place throughout, making every part more negative. The greatest change is on the external surface of the leaf, immediately opposite to the three sensitive hairs. There is no relation between the preëxisting currents and the electrical disturbance consequent on stimulation. The period of latent stimulation (i. e., the space of time occupied by the primary action of the stimulus) is about one-sixth of a second. The period during which the disturbance lasts is about one second. As the leaf becomes fatigued, the period of latency increases to one second and three-quarters, and then most likely the next stimulation produces no effect. The change appears to be a function of the protoplasm of the parenchyma of the region out of which the sensitive hairs arise. Certain of the characters of the change are similar to those presented by muscle and nerve. Why the variation should be a negative one, Dr. Sanderson is unable to determine.

New Shells from Colorado. — In the extensive and remarkable display of natural-history objects brought to the Centennial Exhibition by Mrs. M. H. Maxwell, of Boulder, Colorado, was a box of land and fresh-water shells. These have been examined by Mr. Ernest Ingersoll, who made careful studies of the Rocky Mountain mollusks in connection with the United States Geological Survey in 1874, and summarized his results in an article printed in this magazine for May, 1876. Boulder is at the mouth of Boulder Cañon, several miles northeast of Denver, at an altitude of about 5,530 feet above the sea, and on the eastern slope of the main range, where heretofore no shells had been found. The list includes *Zonites arboreus*, *Z. fulvus*, *Patula Cooperi* (living, and very dark and fine), *P. striatella*, *Helix pulchella*, *Cionella subcylindrica*, *Vertigo* ——? (very minute), *Succinea lineata*, *S. Nuttalliana*, *Limnea palustris*, *L. desidiosa*, *L. humilis*, *Physa heterostropha*, *Planorbis bicarinatus*, *P. tumens*, *Helisoma plexata*, *Gyranlus parvus*, *Ancylus* ——?, *Goniabasis livescens*, *G. pulchella*, *Sphærium striatinum*, *Pisidium abditum*, and an anodon hardly identifiable.

The collection is remarkable, as coming from the eastern slope of the range, and embracing some unexpected species from east and west. As usual, the *Physas* are *Protean* in form, and one can make half a dozen "species" out of them, if disposed. Some of them are well-marked "*Inflata*." Both the planorbs are reported for the first time from Colorado. *P. bicarinatus* is a well-known Eastern shell; *P. tumens* has hitherto been supposed to be confined to Northern Mexico and Southern California. The *Helisoma* is a new form, discovered by Mr. Ingersoll in an isolated mountain-lake in the southern part of the State, and Mrs. Maxwell finds it at Boulder in a similar situation. Both the *Melanians* and the *Sphærium* are additions to the fauna of the State, and the *Anodonta* will probably prove to be undescribed. Mrs. Maxwell proposes to search still more carefully when she returns, and further information on the geographical distribution of our mollusks in the mountainous territories may be expected from various other quarters where research has been stimulated by the curious results already brought out. Colorado seems to be a meeting-ground for mollusks from all directions, and is a promising field for the collector and student.

Marey's Experiments on the Action of the Heart.—Experiments made by Marey show that a diminution of excitability and a rise of temperature in the muscular tissue of the heart invariably coincide with the cardiac systole, while the opposite phenomena are manifested during diastole. The same author has recently attempted to ascertain whether any corresponding variations of the cardiac muscle could be made out. The galvanometer, owing to the inertia of its needle, is unsuitable for the observation of sudden changes in the intensity of currents. Hence, in Marey's experiments, Lippmann's electrometer was employed. The heart of a frog was placed on two unpolarizable electrodes, one supporting the apex of the ventricle, while the auricles rested on the other. Two successive negative variations of the current were indicated by the electrometer during each cardiac systole; one of these was sudden, and corresponded with the abrupt contraction of the auricles; the other was more gradual, and coincided with the slower

movement of the ventricle. The phases of electrical variation are thus seen to be similar to those of the work done by the muscle.

College Exploring Expeditions. — We learn from the *Tribune* that the present Senior Class of Princeton College has organized a scientific exploring expedition to the West. An association has been formed to train men in scientific studies, and fit them as far as possible for the work to be done. The plan of the association's work is as follows: A knowledge of geology, as good as can be obtained, is required of each man. Then the work is mapped out into subdivisions of natural history and paleontology, and from these each one selects a specialty for himself. The meetings are held fortnightly. At these, the association generally receives an address from some scientific member of the faculty. After this, scientific papers are read by the members, in alphabetical order, four each evening. A question chosen at the previous meeting is then discussed. The faculty have given a room, have arranged the studies to help the association as much as possible, and given facilities for special and outside work. The association is forming a working collection of fossils and minerals, not intended to be complete, but typical. In the mean time the executive committee are taking steps to secure government aid in the shape of wagons, mules, etc., and to get the most favorable possible terms from the railroad companies. If, as is hoped, the committee is successful in obtaining free passes, the expenses will probably not exceed $100 per man. It is not yet fully determined what portion of the West will be explored—probably, however, the Green River, in Wyoming Territory, and Yellowstone National Park, or else the Wahsatch Mountains, will be selected. The membership is limited to thirty regular and ten alternate members. Vacancies occurring in the regular membership are filled from the alternates, who attend all meetings, and perform regular duties.

Eucalyptus as an Anti-Periodic.—Two instances are cited by Dr. Curnow, of London, of the cure of intermittent fever by the use of tincture of *Eucalyptus globulus*. We give in full the author's account of one of these cases, as sufficiently illustrating the action of the drug: S. S——, aged eighteen, a Norwegian, was admitted to King's College Hospital, May 23, 1876. He had been suffering from intermittent fever for four or five weeks. The attacks were moderately severe and of a well-marked tertian type. An expectant plan of treatment was pursued until June 9th, and during this period the paroxysms recurred on alternate days with the utmost regularity. They began at 10 A. M., reached their acme between 1.30 and 3 P. M., and passed off about 6 P. M. The highest temperatures varied from 104.8° to 105.6°. On June 9th the tincture of the *Eucalyptus globulus* was given in one-drachm doses three times daily. The next day, on which another attack was due, his temperature rose to 100°, and on the 12th to 100.4°; and after this date no further paroxysm occurred during the remainder of his stay in the hospital.

Improvements in Iron-Manufacture.—Dr. Andrews, in his inaugural address at the Glasgow meeting of the British Association, referred to the many improvements recently introduced in iron-manufacture. But there yet remains, he said, ample work to be done. The fuel consumed in the manufacture of iron, as indeed in every furnace in which coal is used, is greatly in excess of what theory indicates, and the clouds of smoke which darken the atmosphere of English manufacturing towns, and even of whole districts of country, are a clear indication of the waste, but only of a small portion of the waste, arising from imperfect combustion. The depressing effect of this atmosphere upon the working-population can scarcely be overrated. At some future day the efforts of science to isolate, by a cheap and available process, the oxygen of the air for industrial purposes, may be rewarded with success. The effect of such a discovery would be to reduce the consumption of fuel to a fraction of its present amount; and, though the carbonic acid would remain, the smoke and carbonic oxide would disappear. In the mean time, Dr. Andrews suggests that in many localities the waste products of the furnace might

be carried to a distance by a few horizontal flues of large dimensions, terminating in lofty chimneys on a hillside or distant plain, as is done at the mercury-mines of Idria and some other places. With a little care in the arrangements, the smoke would be wholly deposited in the horizontal flues, and would be available for agricultural uses.

The Tomato-Plant as a Protection against Insects.—In a peach-orchard planted by M. Siroy, a member of the Valparaiso Society of Horticulture, the trees at first grew well and strongly. But, on commencing to bud, they were invaded by the curculio; and this insect was followed, as frequently happens, by ants. While the trees were thus infested, the idea occurred to M. Siroy that by placing leaves around the trunks and branches he might ward off the rays of the sun, which were very powerful. For this purpose he happened to choose tomato-leaves. On the following day he found the trees entirely free from their enemies, not one remaining, except here and there where a curled leaf prevented the tomato from exercising its influence. These leaves he carefully unrolled, placing upon them fresh ones from the tomato-vine, with the result of banishing the last insect, and enabling the trees to grow with luxuriance. Wishing to carry the experiment still further, he steeped in water some fresh leaves of the tomato, and sprinkled with this infusion other plants, roses and oranges. In two days these were also free from the innumerable insects which covered them.

The Age of Paleolithic Man.—Dr. R. H. Tiddeman contributes to *Nature* for October 5th a paper in which he reaffirms the inter-glacial age of paleolithic man and of the fauna with which he is associated. The position not only of human but of animal remains points clearly to the fact of their existence subsequent to a deposit of glacial drift, but previous to another deposit of similar material. The facts may be taken as part of the evidence which proves the disappearance of a great ice-sheet which covered Scotland, England, and portions of the Continent, and the return of it after a period of temperate climate during which man and animals inhabited the region.

The direct evidences of the inter-glacial age of paleolithic man from the actual infraposition of his bones or implements are stated as follows:

1. Victoria Cave, Settle: *a human fibula* under glacial till, and associated with bones of *Elephas antiquus*, *Rhinoceros leptorhinus*, hyena, hippopotamus, etc.

2. At Wetzikon, Canton Zürich, a piece of lignite containing *basket-work* lying beneath glacial deposits, and associated with *Elephas antiquus* and *Rhinoceros leptorhinus*.

3. Near Brandon, Suffolk, *implements* with bones not yet determined in brick-earth beneath the great chalky bowlder-clay of East Anglia.

Dr. Tiddeman says the "Settle till is undoubtedly of the age of the ice-sheet. The Wetzikon lignite lies upon a glacial till beneath a river-gravel on which are great erratic blocks clearly indicating the presence of a great glacier posterior in date to the organic remains. The Brandon implements are beneath the chalky bowlder-clay."

Inequality of the Ocean-Bed.—In opening the Geographical Section of the British Association at Glasgow, Captain Evans said that it was learned for the first time by the Challenger's results—ably supplemented as they had recently been by the action of the United States Government in the Pacific, and by an admirable series of soundings made in the exploratory German ship-of-war Gazelle—that the unbroken range of ocean in the southern hemisphere was much shallower than the northern seas; that it had no features approaching in character those grand abysmal depths of 27,000 and 23,500 feet found respectively in the North Pacific and North Atlantic Oceans, as the greatest reliable depths recorded did not exceed 17,000 feet. The general surface of the sea-bed presented in general to the eye, when graphically rendered on charts by contour lines of equal soundings, extensive plateaux varied with the gentlest of undulations. There was one great feature common to all oceans, and which may have some significance in the consideration of ocean circulation, and as affecting the genesis and translation of the great tidal wave and other tidal

phenomena, of which they knew so little—namely, that the fringe of the seaboard of the great continents and islands, from the depth of a few hundred feet below the sea-level, was, as a rule, abruptly precipitous to depths of 10,000 and 12,000 feet. This grand escarpment was typically illustrated at the entrance of the British Channel, where the distance between a depth of 600 feet and 12,000 feet was in places only ten miles. Imagination could scarcely realize the stupendous marginal features of this common surface depression.

Purification and Deodorization of Petroleum Products.—Mr. S. E. Johnson, of Ashby-de-la-Zouch, England, has discovered a method of treating petroleum and other mineral oils, by which those useful hydrocarbon liquids are not only purified, but also deodorized; and that in a simple and inexpensive manner. Chloride of lime is first introduced into the cask or other receptacle containing mineral oil or spirit, in the proportion of about three ounces of chloride, more or less, to each gallon of the liquid, according to the degree of its impurity, and thus chlorine-gas is evolved in the oil or spirit. If necessary, the evolution of the gas may be assisted by pouring in hydrochloric acid, agitating the contents of the receptacle so as to bring the whole of the liquid into intimate contact with the chlorine-gas. The oil or spirit is then passed into another inclosed vessel containing slaked lime, which, having an affinity for the chlorine, absorbs the same, leaving the liquid sufficiently deodorized and purified.

Physiological Effects of Coca.—A correspondent of the *Lancet*, a physician, states that the use of the tincture of coca, in a two-ounce dose, corrected the "unruly throbbing" of his heart, which had been wont to interfere with his accuracy of aim in fowling. This writer had previously taken the tincture in doses of one-half ounce and one ounce without perceptible effect; but, having on the third day increased the dose to two ounces, his composure was perfect at the critical moment. "As soon as the dogs pointed," he writes, "I expected the usual inward commotion, with its usual results; but, to my surprise, nothing of the kind happened. 'Eureka!' I said to myself; 'the coca has made me a steady shot.' So in fact it subsequently proved. Judged by the effects described," he continues, "coca would seem to be inhibitory as regards the action of the heart. Whether this result is produced by indirect action through the mental functions upon which the drug is said to act remains to be proved." Another correspondent of the same journal, not a physician, states that while traveling in Bolivia at great altitudes, such as from 13,000 to 14,000 feet above the sea-level, he experienced marked benefit from eating the leaves. Nearly all travelers on the Peruvian and Bolivian Andes use the drug as a remedy for that effect on the brain and lungs, produced by rarefied air, which in South America is called *zorroche*. One use to which it is put by the Indians is that of a "pick-me-up" after a debauch on alcoholic fluids. In Bolivia it is generally eaten with a paste made of wood-ashes and potato. The writer propounds the belief that the leaf loses its virtue in transmission. This is quite possible. It is an undoubted fact that the *Cannabis Indica*, for instance, loses its potency in crossing the sea. It would seem desirable that a certain quantity of the coca-leaves should if possible be packed in an air-tight case. The price of coca at La Paz, where the best is procured, was last year sixteen dollars per packet of twenty-five pounds.

The American Forestry Association.—The American Forestry Association held its first meeting at Philadelphia in September. Addresses were delivered by Dr. Franklin B. Hough, of Lowville, New York, Mr. McAfee, and Mr. Meehan. Dr. Hough gave an account of the efforts made by various European governments to preserve forests and to promote timber-culture, and showed that the Constitution of the United States, and those of most of the States, give the right to interfere for the preservation of our forests. Mr. McAfee reported on the condition of forest-culture in the West, showing how the planting of trees had been going on to an immense extent, and that it was found that the old notions about the slowness of timber-growth had been derived from the hard struggle with Nature that wild timber had

to make. Cultivated trees had grown so much faster than was expected that people had been surprised at the growth, and it was now becoming generally known that wood came into profit much sooner than was thought possible years ago, and forest-culture was much more popular in consequence. In his State at least 80,000 acres of timber had been planted during the past few years, and the work was still going on. He gave figures as to the growth of individual species, chiefly from facts within his own observation. Mr. Meehan, from whose *Gardener's Monthly* we take this account of the meeting, thought that the people, without government interference, can be safely trusted with the care of our forests, and the work of reforestation. Individual effort, encouraged by State laws and agricultural and horticultural societies, would soon replace the decaying forests of our land.

How the Menopoma casts its Skin.—Since reading his "Preliminary Note on the *Menopoma Alleghaniense* of Harlan," before the American Association, Grote has observed in the aquarium of the Buffalo Society of Natural Sciences the process by which the menopoma rids itself of its outer skin. This thin and transparent membrane is first seen to loosen and separate from the entire surface of the body, appearing at this stage like an envelope or glove in which the animal is contained. By a number of wide gapings, during which the mouth is opened to the fullest extent, the skin is parted about the lips, and then commences to fold backward from the head. Convulsive and undulating movements with the body and fore-legs are employed to extract these from the loose skin. The skin then readily falls backward, as the animal crawls forward and out of it, until the hind-legs are reached, when the menopoma turns round upon itself, and, taking the skin in its mouth, pulls it over the legs and tail. The operation reminds one of taking off clothes. The cast-off skin is retained in the mouth and finally swallowed. The operation is quickly performed.

Poisonous Cooking-Utensils.—The danger attending the use of porcelain-lined cooking-vessels was pointed out at a meeting of the British Society of Public Analysts, by Mr. Robert R. Tatlock. He stated that the milk-white porcelain enamel with which cast-iron cooking-vessels are now so commonly coated is in the highest degree objectionable, on account of the easy action on it of acid fruits, common salt, and other substances, by means of which lead and even arsenic are dissolved out in large quantity during the process of cooking. It was shown that it is not so much on account of the presence of large proportions of lead and arsenic that these enamels are dangerous, but because they are so highly basic in their character, and are so readily acted on by feebly-acid solutions. He thought that no enamel should be admitted to use unless it was totally unaffected by boiling with a one-per-cent. solution of citric acid, which was a very moderate test. Further, he gave it as his opinion that either the use of such poisonous ingredients as lead and arsenic in large quantity should be entirely discontinued, or that the composition otherwise should be of such a character as to insure that none of the poisonous substances could be dissolved out under ordinary circumstances.

Agencies that formed the Colorado Cañons.—The great cañon of the Colorado is from 3,000 to 6,000 feet deep, through a distance of 200 miles. All the side-streams reach it through profound cañons, and each stream has done, and is still doing, its own work of erosion. The process by which these results are brought about is considered by Prof. G. R. Gilbert, in the *American Journal of Science and Arts*, under three principal heads: 1. Weathering; 2. Transportation; 3. Corrasion.

By weathering, the writer means the disintegration of rock by the action of temperature—beating of rain and changes of vegetation. The process, however, would be greatly delayed if the loosened material was allowed to remain and cover the surface. Hence transportation becomes a powerful agent in erosion, not only by exposing the disintegrating surfaces, but by mechanical wear in the act of removal.

All rocks are more or less soluble in water, and impurities in the water intensify solvent action. But it usually happens that

rocks disintegrated in this way merely fall to pieces, the hard portion remaining in the shape of sand or pebbles. The transportation of this by streams produces what the author calls *corrasion*. In this way the bed of a stream is widened and deepened, but the work is also facilitated by the ceaseless action of water in dissolving the rocks.

The mechanical wear or erosion by a stream depends largely on its velocity. "A stream of water flowing down its bed expends an amount of energy that may be measured by the quantity of water and the vertical distance through which it descends."

The velocity of a stream would continually increase if none of its energy was consumed in friction, but very much of it is so consumed, and reappears in innumerable forms of movement or subsidiary currents. It is by some of these that the work of transportation and erosion is largely done. But a stream may be overloaded with detritus, and its corrading power correspondingly diminished. "Only with a partial load does a stream wear its bottom." Of the Colorado plateau the author says that the erosion which began with the first lifting of a part above the ocean has progressed continually to the present time. The total uplift has been about 12,000 feet; only 7,000 feet remains, that being the present altitude above the level of the sea. Five thousand feet of the general surface has been removed, and an amount greater by several thousand feet has been corraded by the rivers.

Improved Railway-Signal.—A simple and effective railroad-signal, in use on the Boston, Lowell & Nashua Railroad, is described in the *Scientific American*. A single-cell Callaud battery is connected to the two rails at one end of a given section of the line—say, two miles in length—each section being insulated from adjoining sections. At the other end the signal has an electro-magnet similarly connected to the two rails. When the circuit is closed, as is normally the case, the magnet is excited and the signal controlled thereby so as to show that the line is clear. But, when a train runs on the section, then a shorter circuit is made by the wheels and axles, and the current returns to the battery by this course, instead of passing through the signals. The magnet ceases to attract, and the signal by mechanical means is at once turned, to indicate danger. It is obvious that this must occur as long as a single car remains on the track, or when the circuit is broken by a displaced or ruptured rail or any other cause. Hence the device may be applied over an entire line, and will indicate the condition of every section to a train about to enter on the same. It is found to be operative in all weathers.

Powder-Paper.—A substitute for gunpowder has been invented in England, called "powder-paper," viz., paper impregnated with a mixture of potassic chlorate, nitrate, prussiate, and chromate, powdered wood-charcoal, and a little starch. The powder-paper is rolled into the shape of a cartridge of any required length or diameter. The manufacture involves no danger, it is said; no explosion can take place except by way of contact with fire. The powder-paper leaves no greasy residue on the inside of the gun; it also produces less smoke, gives a less violent recoil, and is less impaired by humidity than gunpowder. With equal charges, by weight, of gunpowder and powder-paper, the penetrating power of the latter is $\frac{5}{16}$ greater than that of the former.

October Meteor-Shower.—In a letter to the *Tribune*, dated October 19th, Mr. Daniel Kirkwood states that shooting-stars in unusual abundance were observed by several trustworthy witnesses at Bloomington, Indiana, on the evening of the 18th, from six hours forty-five minutes to nine hours. The meteors appeared to radiate from Auriga, or rather from a point between Taurus and Auriga. Most of the meteors were small, though two of them possessed extraordinary brilliancy. In a small work on comets and meteors, published three years ago, Mr. Kirkwood called attention to the fact that meteoric showers had been observed at the same period of the year in 1436, 1439, 1743, and 1798. Returns of the shower were observed in 1838 and 1841. He recommends that a careful watch be kept in future about the same period—say, from the 16th to the 20th of October.

Do Plants absorb Diatoms?—Prof. John Phin, in the *American Journal of Microscopy*, criticises the results of Wilson's microscopic examination of wheat-straw grown on land which had been treated with infusorial earth. The substance of Prof. Wilson's paper we gave in the September number of the MONTHLY. Prof. Phin reproduces Wilson's engraved representation of the diatom forms said to have been found in the remains of the straw after treatment with nitric acid, and says: "A single glance at the engraving is sufficient to convince any microscopist that Prof. P. B. Wilson never saw 'upon the field of his microscope,' under the circumstances which he has described, the objects which he has delineated. . . . Bearing in mind that these organisms, as figured, have been obtained by destroying the organic matter with nitric acid, we find *Bacillaria* figured as it exists only in the living condition—the frustules being joined together in the peculiar way which has given to this form the specific name *paradoxa*. For this diatom to have passed through a bath of nitric acid, and come out in the condition figured, would have been almost as great a miracle as the passing of Shadrach, Meshach, and Abednego, unscathed through the fiery furnace of Nebuchadnezzar. So, too, we find a *calcareous* foraminifer figured under the same circumstances. After such instances, the numerous minor features which are utterly irreconcilable with facts may be safely passed over."

Another Way of securing the Chestnuts.—The following narrative is taken from the *Chronique de la Société d'Acclimation;* we give it for what it is worth: "A Frenchman, fifteen years resident in the Transvaal Republic, where he has established a number of plantations, recounts to us the following fact, which no naturalist has as yet reported: The coffee-plantations are much exposed to the ravages of the great cynocephalous monkeys. Among the coffee-plants there grows a shrub, the scientific name of which I have not been able to ascertain, which has its fruit growing very near the trunk. Some wasps, of a kind whose sting is very painful, had chosen several of these bushes for attaching to them their eggs, and the cynocephali were often seen eying the fruit very eagerly, but they dared not touch them for fear of the wasps. One morning, the planter heard terrible cries, and with the aid of a good opera-glass was enabled to witness an interesting spectacle. A fat old monkey, the leader of the troop, would take hold of the young ones, and pitch them repeatedly into the middle of the bush, despite their cries and groans. The shock brought down the wasps' nests, and the irate insects attacked the victims; meanwhile the old rogue quietly ate the fruit, throwing down the remnants of the meal to the females and young ones on the ground."

Taking Impressions of Plants.—M. Bertot, of the Paris Academy of Sciences, offers a simple method of taking impressions of plants. A sheet of paper is first lightly oiled on one side, then folded in four, so that the oil may filter through the pores, and the plant may not come into direct contact with the liquid. The plant is placed between the leaves of the second folding, and in this position pressed (through other paper) all over with the hand, so as to make a small quantity of oil adhere to its surface. Then it is taken out and placed carefully on white paper; another sheet is placed above, as two impressions can be taken at once, and the plant is pressed as before. On now removing it, an invisible image remains on the paper. Over this you sprinkle powdered black-lead, which causes the image to appear. With an assortment of colors, the natural colors of plants may be reproduced. To obtain fixity, resin is mixed with the black-lead in small quantity; the impression is fixed when it is exposed to a heat sufficient to melt the resin.

Ancient Weapons.—Among the Michigan exhibits of ancient stone and copper implements at the Philadelphia Exposition is a weapon fashioned after the model of the "patu-patu" of New Zealand. It is described by Dr. C. C. Abbott, in the *American Naturalist*. The patu-patu of New Zealand is, according to Tylor, quoted by Dr. Abbott, "an edged club of bone or

stone," in shape "like a soda-water bottle with the bulb flattened. It is a very effective weapon," he adds, "in a hand-to-hand fight, being so sharp that a man's skull may be split at one blow with it." The Michigan specimen is 16¼ inches long. It is 2⅝ inches wide for 11 inches; then it tapers to 1½ inch, but again widens to 2 inches at the end, thus forming a terminal knob. The edges are beautifully wrought, and are as sharp now as most of the polished stone axes and celts. In the vast collection of relics of American aborigines at Philadelphia Dr. Abbott finds no other specimen of the form here described, and it is presumable that this weapon was one seldom fashioned in North America.

NOTES.

A MEETING of persons interested in the formation of a Metrological Society was lately held in Boston, which resulted in the organization of the "American Metric Bureau." Arrangements were made to secure a large list of honorary or life members, and to solicit subscriptions to supply teachers with metric apparatus at half-price. The assessment for 1876 was fixed at $2.50. The list of directors is as follows: Samuel W. Mason, J. P. Putnam, Prof. W. F. Bradbury, Dr. Edward Wigglesworth, Melvil Dewey, Prof. William Watson, Dr. H. P. Bowditch, S. S. Greene, Nathan Appleton, and Prof. K. S. Pennell.

IN the Paris School of Mines is a laboratory, founded in 1845, for analyzing gratuitously any substances presented. Last year 767 analyses were made at this laboratory, chiefly of minerals and manures. A laboratory for the gratuitous analysis of medicines and articles of food would be a very useful institution in our American cities.

CREMATION of the dead is now fairly established in Saxe-Gotha. In a recent sitting of the town council, it was decided to erect the necessary apparatus in the new cemetery. Cremation is to take place only in accordance with the clearly expressed wish of the deceased, and under permit from the proper medical officer. The ashes are to be gathered in urns, to be preserved by the family of the deceased, or set up in a hall in the cemetery.

IN one of the monthly reports of the Department of Agriculture, it is stated that in Livingston County, Illinois, the planting of trees in groves and shelter-belts, and for ornamental purposes, is now very general. The black-walnut is the favorite tree for profit and ease of cultivation; but elm, soft maple, willow, cottonwood, European larch, and ash, are common, while evergreens are popular for ornamental purposes, and occasionally are planted in groves and shelter-belts.

AT the Agricultural Congress in Philadelphia, resolutions were offered by Prof. C. V. Riley, and unanimously adopted, in favor of government action for the suppression of the Rocky Mountains locust-plague. In the opinion of the Congress, the national Legislature owes it to the people of the West to take this matter into consideration, and the United States are called upon to follow the example of other nations under like circumstances, and appoint a special commission for the thorough investigation of the subject.

IN a work on the "Voices of Animals," by Landois, additional evidence is collected of the universality of vocal sounds among the lower animals, including the Mollusca. The author considers it to be indisputable that ants possess a vocal speech, by which they are enabled to exercise those higher mental faculties to which they owe their high social organization.

THE University of Michigan had last year 101 female students, distributed as follows: Medicine, 37; law, 2; homœopathy, 2; literature, 60. "The experience of the past year," writes the president of the university in his annual report, "confirms the opinion we have been led to form by the experience of former years, that women who come here in good health are able to complete our collegiate or professional course of study without detriment to their health."

PROF. MAURICE SCHIFF, of Florence, has demonstrated that the non-edible mushrooms, "toadstools," contain a common poison, *muscarine*, and that its effects are counteracted by either atropine or daturine. Italian apothecaries now keep these drugs in the rural districts, where the consumption of the non-edible fungi is apt to occur. The hint is worthy of attention everywhere.

IT has been affirmed that not less than four per cent. of all the coal-laden vessels that have left English ports during the last five years, for destinations south of the equator, have suffered either total or partial loss by the spontaneous ignition of their cargoes.

At the recent meeting of the British Association, Mr. Garner stated that he had found from measurements of brain capacity, and from casts of the interiors of skulls, that the size of the brain in the dog does not correspond very closely with the size of the animal. No dog has so large a brain as the wolf, nor one so small as the jackal. The brain of a Newfoundland dog is very little larger than that of a terrier. Prof. Macalister, of Dublin, gave an account of the brain of the celebrated greyhound "Master Macgrath." He had weighed the brain of many other dogs, but Master Macgrath's was the heaviest of all, and the convolutions were much more complex.

In a balloon-voyage from Cherbourg, in August, two French aëronauts, Moret and Durnof, observed with surprise, at a height of 1,700 metres, that the bottom of the sea was visible in detail, though that part of the British Channel must have a depth of 60 to 80 metres. The rocks and submarine currents appeared with great distinctness. It is suggested that this fact might be utilized, a means being afforded of giving accurate representations of the bottom for the benefit of navigators.

In the *Scientific Farmer* we find recorded the death of Prof. Dimond, of the New Hampshire Agricultural College. He, no doubt, died of overwork. In the Agricultural College he was Professor of Agriculture, Botany, and Chemistry, farm-superintendent and steward, and at the same time was Professor of Botany and Chemistry in Dartmouth College. It is stated that three men will be appointed to perform the duties recently performed by Prof. Dimond.

During the past year the French Association for the Advancement of Science expended the sum of 7,000 francs in aid of scientific research. Of this sum, 5,000 francs was granted to the astronomer Janssen, to help defray his expenses as a member of the expedition to observe the transit of Venus; and 2,000 francs to M. Chapelas-Coulvier-Gravier, to enable him to continue his observations of shooting-stars.

At one point on the margin of Lake Tanganyika (Central Africa), Captain Cameron saw large masses of coal. In the district adjoining Manyuema iron is plentiful: the people manufacture large quantities of iron, and many of the articles they make are beautifully finished.

Prof. H. N. Martin will lecture on animal physiology, in the John Hopkins University, Baltimore, on Tuesdays and Fridays during the winter. The lectures will be accompanied by instruction in the laboratory. After the spring vacation, Prof Martin will deliver a course of lectures on general biology, intended for elementary students. There will also be organized, during the latter part of the session 1876–'77, a short course of more advanced lectures on embryology.

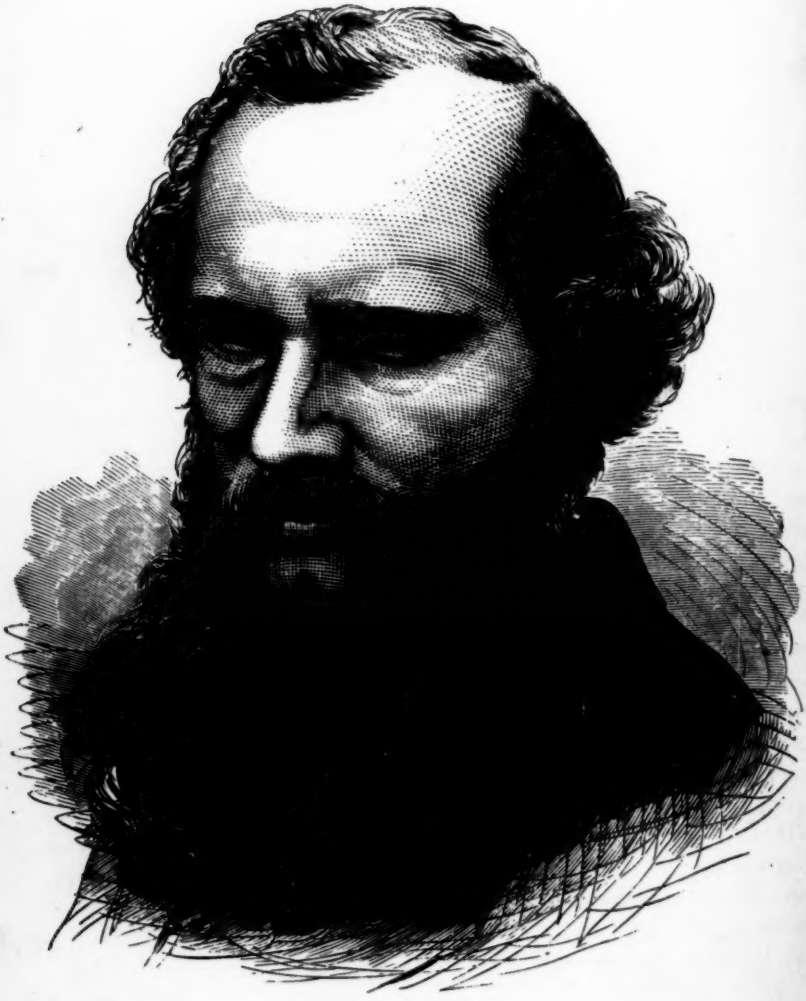
The formation of nickel-ore near Lancaster, Pennsylvania, is pronounced by the *American Manufacturer* to be the heaviest so far discovered in any part of the globe. The ore is exceedingly rich, of a grayish tint, very heavy, and so hard and closely united to the surrounding substances that it has to be got out by blasting. As soon as the ore is mined, it is crushed into small pieces, and then transferred to kilns of a capacity of from eighty to ninety tons each. It is then subjected to heat obtained at first by burning wood, and which is continued by the conversion of the evaporating fumes. The manipulation is concluded by the fused metal being placed in a smelting-furnace, and undergoing a process similar to that adopted in the treatment of iron-ore.

A Berlin machinist has invented a steam-velocipede. The boiler is heated by means of a petroleum-lamp, and rests on the axle of the hind-wheels.

The Paris correspondent of the London *Times* states that, in digging the new basin at St.-Nazaire, animal remains, tools, weapons, and utensils, have been found in a sandy stratum 20 feet below the surface. Last year a dolichocephalous skull was found near the same spot.

The Registrar-General of Great Britain and Ireland, in his quarterly return, states that the births of 296,350 children, and the deaths of 171,082 persons of both sexes, were registered in the United Kingdom in the three months ending June 30, 1876. The recorded natural increase of population was thus 125,268. The registered number of persons married in the quarter ending March 31, 1876, was 117,760. The resident population of the United Kingdom in the middle of 1876 is estimated at 33,093,439; that of England and Wales at 24,244,010, of Scotland at 3,527,811, and of Ireland at 5,321,618.

Dr. Magnus condemns the use of blue glasses as a protection for the eyes, and prefers the gray and smoky glasses used in England. He considers blue glass specially irritating to the eye, and says that many birds, reptiles, and amphibians, have yellow or reddish oil-drops in the eye to neutralize this blue color and protect the eyes.



SIR WILLIAM THOMSON.